Annual 1990

Research

91-04264/

Cover Photo

Surface science techniques have applications central to ensuring the reliability of Ontario Hydro's generating plants and also fundamental value to studies of corrosion-inducing mechanisms. Here, prior to examination by Auger spectroscopy, a metal foil is being inspected visually for surface defects.

Table of Contents

Vice President's Message	2
Director's Message	3
Leadership Through Innovation	4
Divisional Activities	
Generation	16
Delivery	20
Utilization	23
Environment	25
Support Services	
Divisional Projects	28
Divisional Services	30
Operations Research	32
Departmental Overviews	34
Awards and Achievements	36
Resources and Costs	38
Glossary	40
Publications	41
Presentations	46
Significant Research Contribution	Inside Back Cover

Vice President's Message

One of the challenges faced by all innovators is that of getting their ideas implemented and their products used. This process, technology transfer, is crucial to innovation. The Research Division is no exception, and the transfer of technology both internally and externally is an important part of its mandate. This process has been ongoing for over 75 years, and the innovations produced by the Division have helped make Ontario Hydro a world leader in the electric power industry.

By facilitating the transfer of technology to industry, both that developed by Hydro and by others, the Research Division helps Ontario's manufacturers use energy, particularly electricity, more effectively. The Division's assistance given to one Ontario manufacturing company helped to improve the efficiency of its heat pump products, thereby improving competitiveness and providing the potential to reduce electrical demand in the province. In another instance, an innovation in continuous casting technology currently being transferred to a local steel producer will potentially result in large electrical energy savings, thus providing benefits both to the producer and Ontario Hydro.

Other avenues for technology transfer are being used. Representatives of industry ask the Division's experts to participate in manufacturing consortia and to support new products that incorporate innovations produced by the Division. New Business Ventures Division actively markets the Research Division's products. Technology transferred to industry in this way helps Ontario industry and returns some of the money invested in research to the Corporation. New Business Ventures Division is also participating in a new venture, IRIS Power Engineering. This company, founded by former Research employees, will utilize technology developed by the Division to its own benefit and that of Ontario Hydro.

Over the past eight decades, Ontario industry and the Province have benefited from technology developed by, and transferred from, Ontario Hydro research activities. I anticipate that Hydro's contribution to our Province will continue, with emphasis on helping our customers make effective and efficient use of electricity by applying appropriate technologies to meet their needs.

A.R. Holt
Vice President
Corporate Planning

Colin Campbell (Vice President, Operating Services, Dofasco), Al Holt, Frank Pickard (President and CEO, Falconbridge), and Gordon Thursfield (Vice President, Energy Group, Canada Wire and Cable) discuss the value of more efficient electricity use to Ontario industry.

Director's Message

In 1990, the Research Division successfully met the many demands presented by Ontario's power system. Success was directly attributable to the highly trained and dedicated researchers hired by the Research Division in the past. But what of the future? Will we be able to maintain our record of research excellence into the twenty-first century?

Like the rest of Canadian industry, we require a continuing supply of bright researchers to supply the knowledge and new ideas necessary to provide the innovations we need to remain competitive. Since the late 1960s, science and technology in the Western world have fallen from favour. The emphasis of business and education has shifted away from the creation of wealth to focus on its manipulation. As a result, projections indicate that the supply of qualified researchers will be inadequate to meet the needs of Canadian industry over the next decade.

Ensuring the life of older facilities demands the cooperation of both technical professionals and management. Here, Jim Sato (engineer), Bob Lococo (mechanical maintenance foreman), and Don Mills discuss the refurbishment plans for the Ontario Power Generating Station at Niagara Falls.

While the education system is the foundation of a vigorous science and technology base, it cannot do the job alone. Science and engineering must compete more effectively as career choices for young people. Thus, there must be evidence that these disciplines will provide meaningful and financially rewarding careers. The Research Division plays an important role in the education system. Our researchers give presentations in local schools on careers in science and technology and provide support for other science education activities. Arrangements are made for promising science and engineering students to visit our laboratories. We provide work opportunities for students, both during the summer and during the academic year. Some of our researchers hold adjunct professorships at Ontario universities and participate in the National Sciences and Engineering Research Council (NSERC) industrial postdoctoral program by providing recent graduate scientists opportunities to work in their fields in an industrial setting.

In addition to encouraging students to choose careers in science, the Research Division also provides career opportunities in a number of technical areas as evidenced by the contents of this annual. The Division has taken a leadership role in developing dual career paths in order to provide technical professionals with the same rewards as employees interested in management activities. Continuing job training, challenging work, and opportunities for peer interactions contribute to an exciting environment for rewarding careers in science and engineering.

The opportunities and work environment afforded by Ontario Hydro's Research Division have enabled us to attract and keep a highly qualified staff. Our excellent staff in turn has allowed us to successfully deal with the challenges presented by the power system over the years. I would like to thank the Managers of the Research Division and their staff for contributing to this enviable record in 1990.

D. Mills
Director
Research Division

Excellence, innovation, internationally acclaimed research, and timely commercial implementation allow the best of technology to be turned to Corporate advantage.

Ontario Hydro's central mandate is to provide safe, reliable, and economical electric power to the province of Ontario with due regard for sustaining the natural environment. The utility can also make a substantial contribution to provincial economic development through exploitation of the utility's investment in research and development (R&D). New technologies can do more than provide the solution to specific utility problems; they can also help make Ontario industry a serious contender in today's complex, dynamic, technologically oriented global marketplace.

Until 10 years ago, the Research Division saw its objective as solely the support of Corporate needs. This view has evolved into one that recognizes a secondary objective, that of supporting provincial economic development, especially the electrical needs of Ontario industry. Broadly, the Research Division can serve Ontario by

1. Developing new technologies to increase the efficiency of electrical power utilization;

2. Assisting Ontario industry to exploit new, efficient electrotechnologies;

3. Testing industrial products and services that use or rely on electricity;

4. Developing new products that can be licensed or given to industry for sale to other clients; and

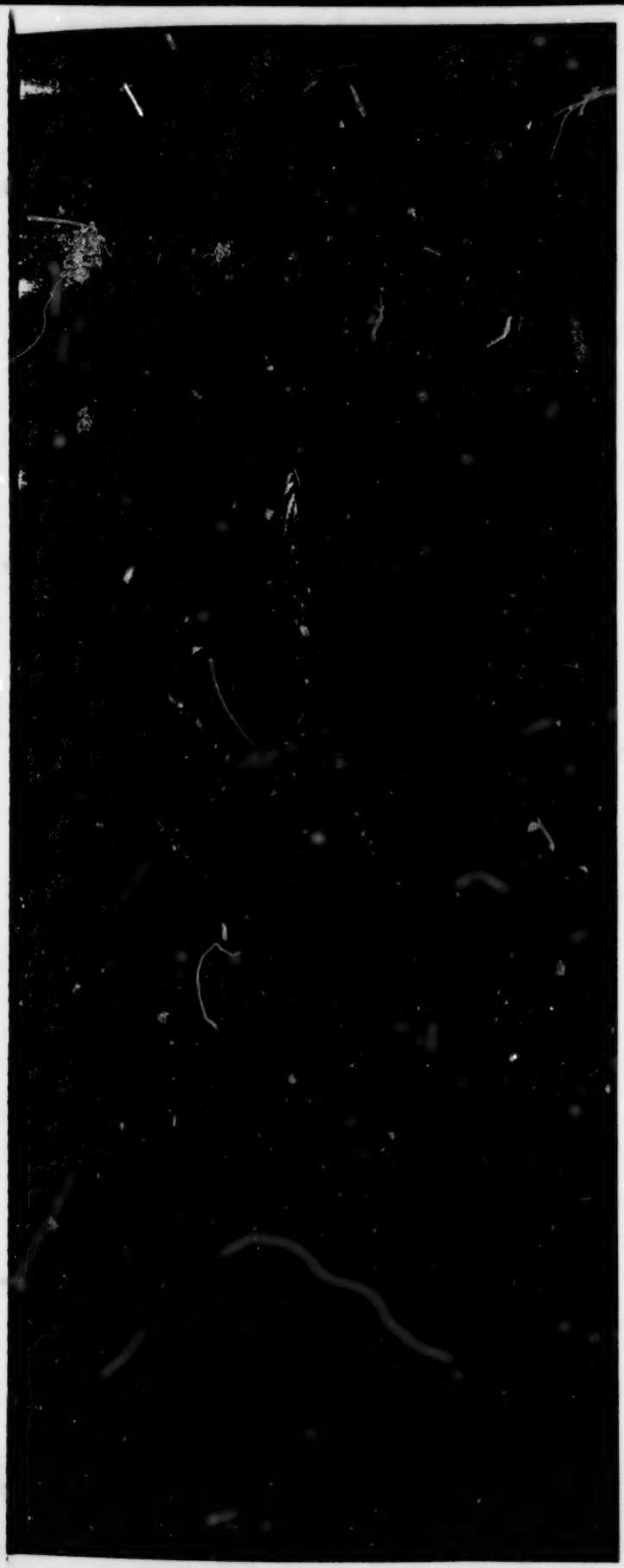
5. Performing contract research for companies in areas where Hydro can provide special expertise and facilities.

Any Ontario Hydro strategy for promoting economic development must first ensure that the electric power it produces be used to its very best advantage. Customer needs must be balanced with available electricity resources. In striving to match the supply and consumption of electricity in Ontario, any effort to improve utilization efficiency can be considered an "efficiency resource" that ranks as high as any other on the supply side of the equation. More efficient electrical utilization is expected to provide the Corporation with the equivalent of a 3 500 MW peak demand savings by the turn of the century.

In support of the Corporate energy management program, the Division seeks to increase the penetration of existing technologies into the marketplace and to aggressively explore the potential of new technologies for future application and development. When in the customer's best interest, the Division helps the Corporation provide customers with the assurance that adoption of an unfamiliar technology will pay off, and with minimum risk to the environment. The Division's extensive research into new heat pump and microwave technology is a prime example of this mandate in action.

Ontario has a climate marked by extremes: its residents cope with extreme winter cold and with considerable summer heat and humidity. Meeting demands for space heating and cooling represents one of the largest energy uses in our climate. Half a million Ontario homes are electrically heated. Collectively, these homes use over 3 000 MW of Ontario's peak load.

Advanced heat pump technologies have been identified by the Research Division as having considerable potential to reduce residential demand. Generally, heat pumps have been developed for climates less severe than ours; however, Ontario's cold winters demand a heat pump with much better winter performance characteristics. This means that Corporate demand management targets can be well served by developing the technology base itself.



Several types of heat pumps can lower the demand for the energy that Hydro produces. A moderate penetration of cold climate air source heat pumps, burner-assisted heat pumps, and ground source heat pumps into the Ontario market could yield at least 300 MW of demand reduction by the year 2000.

A new type of ground source heat pump promises the customer lower capital costs and better performance. Ground source heat pumps use heat present in the earth that has been warmed by the sun and internal sources. Market penetration of this newly available and environmentally friendly technology is being enhanced by a Research Division development that obviates the need for a secondary heat exchange step in its operation. Current systems collect heat from the earth through a buried pipe filled with antifreeze. A heat exchange step is required to transfer the collected heat from the antifreeze to the heat pump itself. The refined model extracts heat directly from the ground via a buried copper refrigerant coil. Direct expansion of refrigerant means that heat from the ground is transferred directly to the pump.

Earth energy systems, such as the ground source heat pump, reduce energy costs for heating and cooling. Customers can save as much as 60 percent on their heating costs and 20 percent on air-conditioning.

In today's technologically-driven world, it is not an exaggeration to say that a new technology must make history quickly, or be consigned to it.

Elimination of the heat exchange step translates to a 20 percent savings in the purchase and installation costs of this new version of the ground source heat pump. Operating costs lower than those of other commercially available heating systems are another advantage. If the operating costs of some popular systems are compared on an annual basis, a homeowner who spends $1 100 on electric resistance heating could expect to spend about the same on oil heating, and $600 on gas heating. This compares with only $400 on the new heat pump system.

Quite apart from the demands of the residential market, industry's needs and expectations for power are growing even as Ontario Hydro's ability to meet those needs diminishes. As Hydro becomes more and more pressed to meet increasing demand and as conventional conservation measures approach the saturation point, further relief can only come from new approaches and new technologies.

Optimizing the spin-off potential of technological advances can give Ontario a competitive edge in the global marketplace. For the Corporation to exploit this potential, the Research Division must ensure the shortest possible time lag between laboratory discovery and safe and economic implementation in the marketplace. In today's competitive world, it is not an exaggeration to say that a new technology must make history quickly, or be consigned to it.

Ontario's steel producers expect substantial cost savings and increased productivity from the development of a new process for the continuous casting of high-grade steel bar products. The concept on which the process is based is simple. A new technological base has allowed the development of a novel radially pulsating mould, which not only produces a better quality surface and internal steel structure, but also integrates the overall casting process.

The Research Division provided research support for the project in collaboration with two major Ontario steel product producers. Funding was provided by Ontario Hydro's Energy Management Branch.

The new continuous casting technology overcomes sticking problems associated with the use of a stationary mould. High-frequency radial pulsation of the mould used in the new, more energy-efficient process results in a marked reduction of friction and, consequently, allows high-speed smooth withdrawal. The result is a cast that is virtually defect free and suitable for further continuous processing.

Ontario Hydro must consider the supply side of the equation as well as the demand side. The utility delivers the power it produces through an electricity grid consisting of integrated 500-kV, 230-kV, and 115-kV transmission networks and extensive distribution systems operating at lower voltages. The delivery system is designed and built to allow Hydro to manage the fluctuations in power flow across the province, including rapidly changing power flow patterns arising from faults, emergencies, and other unusual conditions. Interconnections with neighbouring utilities provide backup to further ensure reliable power delivery. Reliable protection of the components of a system of this complexity is vital. This is especially true of a power system already stressed by high operating demands coupled with the reality of aging equipment.

Within this context, the development of new technologies is particularly important; only through their development can power system growth requirements be met. This is why a substantial portion of Research Division effort is being expended to secure and protect the system and to develop a better understanding of aging mechanisms.

At times, Ontario's winter weather makes ensuring secure power delivery difficult. Insulator flashovers can occur when freezing rain and fog are followed by slowly rising temperatures. On average, the Southern Ontario system might expect this mix of conditions to cause flashover problems every 2 years, but in March 1986, conditions were particularly severe, and a total of 57 flashovers of line suspension and post insulators forced a large part of the 500-kV system out of service. Since that time, a major research program has been underway to gain a better understanding of the phenomena and to develop suitable insulator retrofits for use in vulnerable locations.

The first step was to simulate in the laboratory as closely as possible the specific mix of weather conditions that triggered the events of 1986. The Division's high-voltage laboratory facilities were modified to enable reproduction and control of the variety of factors known to contribute to the flashover mechanism. The combination of factors found to play a key role in producing flashovers were the levels of pollutants on the insulator surface, the rate and amount at which ice formed, and the conditions associated with subzero fog and slowly rising temperatures.

Ontario's steel producers expect substantial cost savings and increased productivity from the development of a new process for the continuous casting of high grade steel.

In the final analysis, it is only operating experience itself that can establish the success of a new technology.

In addition to determining the exact relationship between specific external factors and the flashover event, a complementary research effort resulted in the design of an alternative insulator that exhibits a 20 percent performance improvement over the standard insulator. Polymer insulators are also being evaluated as a means of obtaining better performance at lower cost.

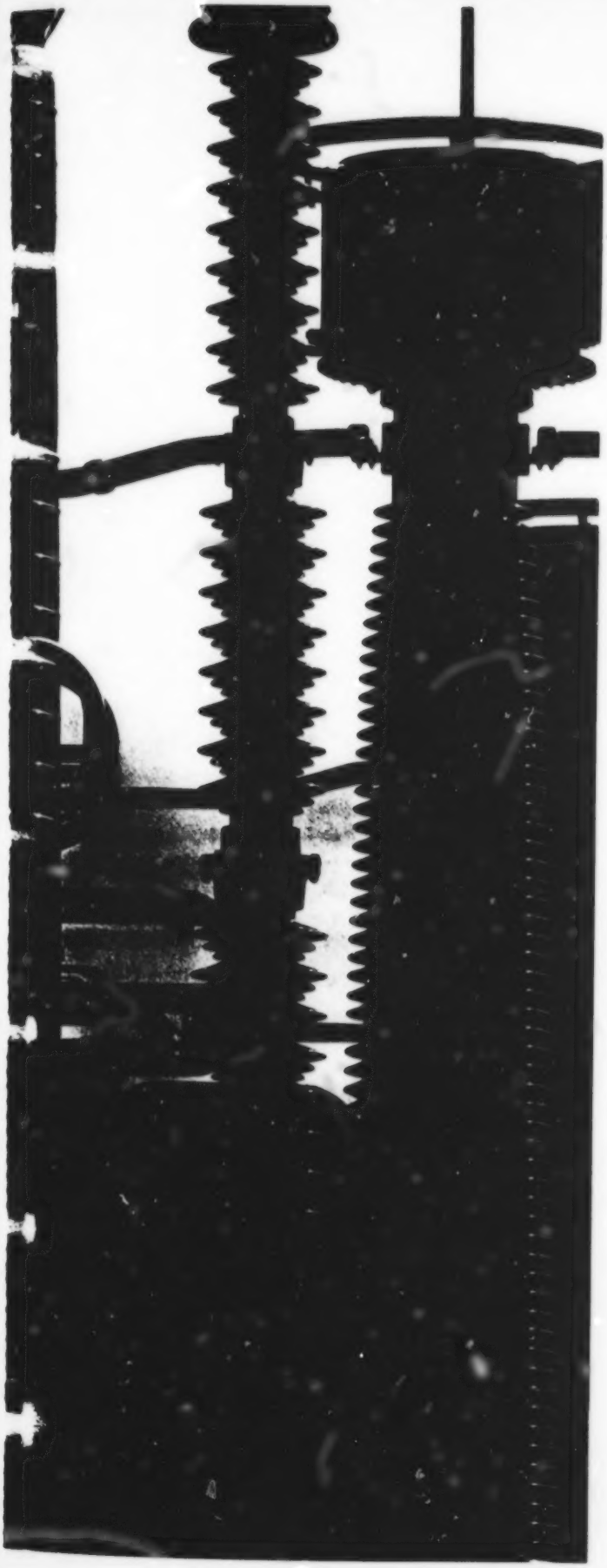
Since the work on outdoor insulators began in 1986, knowledge of weather factors and better simulations have come about as the high-voltage test facility has been upgraded. The big payoff will be improved insulators for stations and lines less vulnerable to flashover under the influence of weather conditions typical of Southern Ontario. For the Division, this means an opportunity to pursue the development of new standards for outdoor insulation; for industry these standards will ensure a better product line of insulators; and for the Corporation a more secure and reliable transmission system. Ontario Hydro leads the world in this area of R&D: no other test facility has the capability of that now in operation at the Research Division.

The work on outdoor insulators has involved the close cooperation of a number of stakeholders elsewhere in Ontario Hydro, which includes System Planning, Design and Development-Transmission; and Power System Operations Divisions. External contracts were also awarded for tasks such as remodelling the fog chamber and for testing the insulators under different conditions. The work on polymeric insulators also involved liaisons with several external organizations, including the Institute of Electrical and Electronics Engineers (IEEE) and the Electric Power Research Institute (EPRI). The work was funded jointly by Ontario Hydro and the Canadian Electrical Association (CEA).

To solve certain transmission line outage problems, new materials that better withstand extremes of temperature and mechanical forces seem to hold much promise. The answer to many types of equipment failure may lie in the development and application of "advanced" materials, which are primarily composites of metals, ceramics, and polymers. The result may be a major opportunity to reduce outages through use of components that possess significantly higher mechanical and environmental stability than those fashioned from traditional materials. As well, transmission line performance will be improved by reducing audible noise, electromagnetic interference, energy losses, and construction costs.

Whereas outdoor insulation reliability is most often a concern of utilities operating in northern climates, the performance of enclosed high-voltage insulation systems concerns major utilities everywhere. As a result, promising insulation techniques are being developed for use in power equipment and underground cables. However, manufacturers and utilities have moved cautiously. In the final analysis, it is only operating experience itself that can establish the success of a new technology.

To reduce the risk of unexpected operating problems associated with the introduction of new enclosed insulation systems, Ontario Hydro has maintained an ongoing research program to assess the performance of SF6 gas-insulated switchgear (GIS) over a period of 15 years. The Research Division has worked successfully with several other Ontario Hydro divisions, a number of utilities in the United States and overseas, universities in Europe and Scandinavia, and manufacturers worldwide to improve the reliability of both existing and future installations. A recent success story concerns the development of an x-ray induced partial discharge (XIPD) technique that allows the study of the long-term aging behaviour of epoxy-based materials when used as insulators.



The XIPD technique significantly improves defect detection in high-voltage insulating materials as well as the long-term reliability of GIS. Given the critical role that switchgear plays in the transmission system, this technique was badly needed. The XIPD technique is expected to provide the basis for a standard industry acceptance test.

Special attention is currently being given to ensuring the long-term reliability of GIS installations. Newly developed diagnostic tests allow early detection of problems that could lead to failure. Early detection of system deterioration allows time for planned rather than forced maintenance. Another concern of researchers is the provision of safe GIS maintenance procedures.

Problems being experienced by Ontario Hydro relating to GIS technology are common to other utilities. In this sense, the Division's activities will benefit the entire GIS user community, especially since Ontario Hydro has the expertise to influence the writing of industry standards.

The tiered weathersheds of new 500-kV station post insulators designed at Ontario Hydro are expected to improve transmission system reliability during winter fog and freezing rain storms.

Nondestructive evaluation of CANDU reactor fuel channel components provides vital information about the performance and life expectancy of critical nuclear plant components.

Yet another Research Division project is aimed at the early detection of potential reliability problems and at facilitating maintenance to preempt machinery breakdown. The ability to assess insulation quality is essential if Hydro is to purchase wisely, to prevent in-service failures, and to make decisions about refurbishment or life extension of large components. Specific diagnostic instrumentation related to generator insulation has been developed. To date, this technology includes two partial discharge tests that can evaluate the condition of stator insulation in operating turbine and hydraulic generators and a voltage endurance test that accelerates aging mechanisms. The endurance test evaluates the ability of insulation to stand up to the stress of operation at high voltage and elevated temperatures. This test has become an IEEE standard, and the partial discharge tests have been commercialized. Both will be used by utilities the world over. In-service winding failures at Hydro are now virtually a thing of the past.

Like other types of power plants, nuclear stations are susceptible to aging. Even the aging of Darlington, not yet fully in service, must be taken seriously because, when this station is on line, nuclear power will account for 60 percent of Ontario Hydro's total energy production. Addressing uncertainties about age-related degradation of many nuclear plant components—there are thousands—is very different from addressing the same uncertainties about transmission and delivery system components. The problem is often one of access. Manual inspection of the components that make up the core of an in-service CANDU reactor is, of course, impossible.

Inspection of CANDU reactor fuel channel components can be best achieved through their nondestructive evaluation (NDE). NDE technologies are complementary to technologies related to the discipline of fracture mechanics.

Whereas fracture mechanics seeks to predict the performance of materials, components, and structures through both analysis and experiments, NDE enhances this technology by the timely discovery of imperfections that may lead to a structure's early failure. Both disciplines meld together to provide information about the performance and life expectancy of critical nuclear plant components.

At this time, it is fuel channels that provide the Corporation with its greatest challenges, both technically and economically. Given the hundreds of tubes in a reactor, the question facing the researcher is how to inspect them for the presence of cracks or defects without incurring immensely costly reactor downtime.

The NDE techniques developed at the Research Division have used CANDU's unique on-power refuelling capability to advantage. Three fuelling-based inspection systems, known at Hydro by their acronyms CIGAR, PIPE, and BLIP, were developed at the Research Division in concert with Central Production Services, Design and Development-Generation Divisions, and Canadian General Electric. The packaged inspection probe system (PIPE), which is used to inspect rolled joints in pressure tubes, was specifically developed to reduce reactor downtime since the standard system, channel inspection and gauging apparatus for reactors (CIGAR), took considerably longer to couple to a pressure tube. PIPE was developed as a response to an Atomic Energy Control Board (AECB) request that rolled joints in older reactors be inspected for delayed hydride cracking.

PIPE worked extremely well during the inspection of Bruce NGS Units 1 and 2. The system was used to inspect almost 300 rolled joints at close-to-design speeds. PIPE was an original and highly cost-effective solution to an urgent problem. At a typical downtime cost of $10 000 per hour, the savings of PIPE over CIGAR amount to over $12 million.

Hydride blisters form on pressure tubes when calandria tube to pressure tube contact occurs. A related concern is how to detect blisters before they become susceptible to cracking. Conventional techniques detect only the cracking not the blistering. Recently, a newly developed technology, which exploits innovative ultrasonic technology and advanced data handling techniques, was applied to perfect an uncracked blister detection module. A blister location inspection package (BLIP) using PIPE was used successfully to inspect pressure tubes in Pickering NGS Unit 4 reactor.

Debris and loose parts in the overall flow systems of nuclear power plants can be introduced inadvertently, particularly in the primary heat transport system, when the system is shut down and opened for routine maintenance. To remove the debris, and repair any resulting damage, requires draining the system, which in turn requires downtime. Downtime in turn necessitates buying replacement power, thereby putting pressure on the utility's finances.

All utilities in the U.S., France, Germany, and Japan have some form of regulatory requirement for on-line loose parts monitoring in their nuclear power plants. Ontario Hydro, although not required by legislation to provide such monitoring, does do so. The currently used system, however, has a major drawback; it requires regular auditory monitoring by highly trained personnel who verify signals as attributable to loose parts or debris. Currently, the human ear is the most sensitive arbiter of whether these sounds are the result of metallic debris or of a process phenomenon such as cavitation. The need for specially and expensively trained personnel leaves stations vulnerable when these individuals leave for other postings.

The Research Division is addressing the problem differently, by means of neural network technology. Unlike the expert system approach to solving problems, which attempts to define the rules of logic used by the brain, the neural network approach emulates the function of neurons. Neural networks can be trained to learn a task, not merely to carry one out.

Neural networks are particularly adept at handling auditory signals, even when a well-defined set of rules about the character of the signals is unavailable. Already success has been achieved in applications where neural networks have demonstrated the ability to emulate some aspects of human hearing. Although sample space in these experiments has been small and the ratio of impact signal to background noise high, the technology would seem to go far to address the need for an automated loose parts monitoring system that obviates the need for costly training of personnel. No work is being done elsewhere on this particular application.

Ontario Hydro, accepting that no form of energy production is entirely environmentally benign, commits to design and execute its development plans in a way that ensures the continued vitality of the environment. The threat of global warming is one that not only Ontario Hydro, but utilities everywhere, must face, given that power production on the global scale releases to the atmosphere billions of tons of carbon dioxide and other gases.

As a responsible power producer committed to a sustainable environment, Ontario Hydro is acutely aware of its responsibilities in this area.

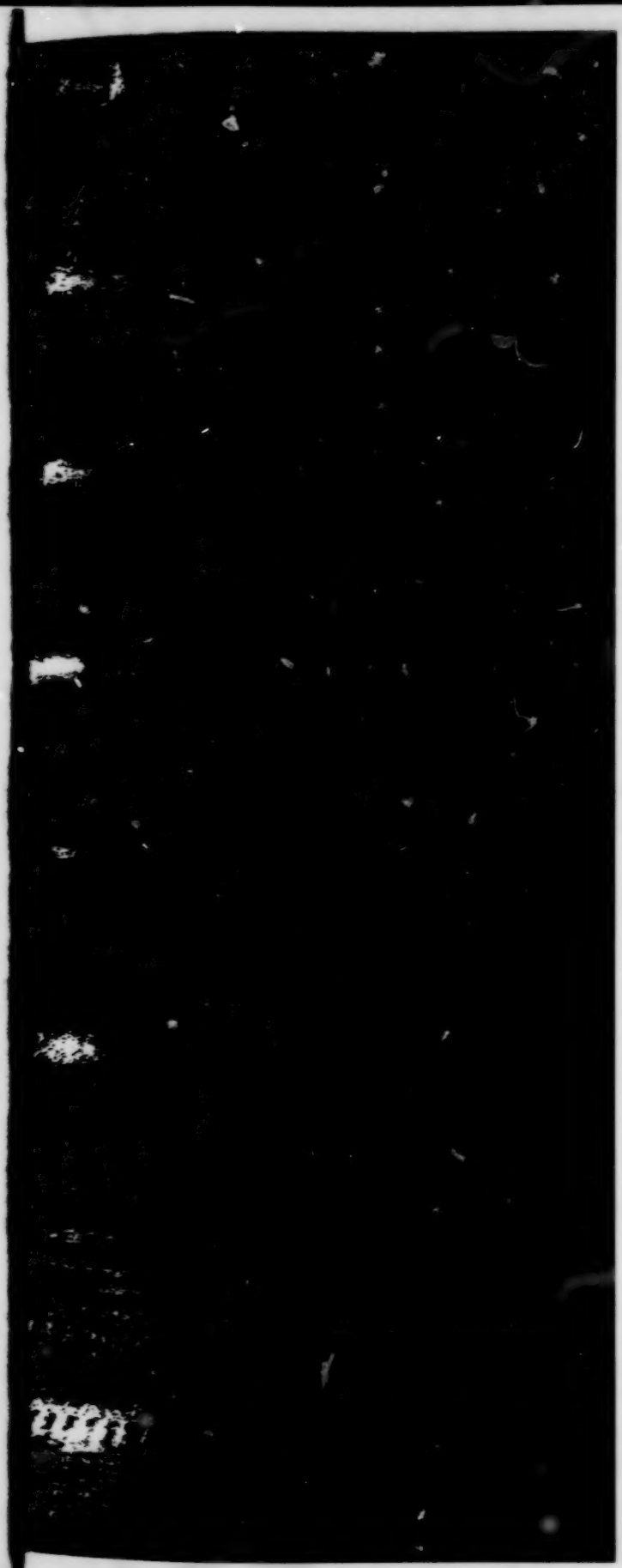
The principles of the greenhouse effect have been understood for over a century. A planet's climate is the product of a delicate balance of energy inputs, chemical processes, and physical phenomena. Some gases, like carbon dioxide and methane, tend to absorb heat in the same way that glass traps heat in a greenhouse, thereby allowing temperatures to build up. The intense heat of Venus is a result of an atmosphere composed mainly of carbon dioxide. Earth's atmosphere is quite different, being dominated by nitrogen and oxygen, whose physical properties do not contribute as hugely to global warming. The concentration of carbon dioxide has varied little over the past several million years, which has created a relatively stable climate conducive to life as we know it on our planet. The term "greenhouse effect" has become part of common parlance not because it is a new phenomenon, but because the industrial age has ushered in changes not all to humankind's benefit. Anthropomorphic activities necessary to fuel industrial production have increased the concentration of carbon dioxide and other so-called greenhouse gases to levels that could upset the delicate balance of the earth's atmosphere.

Not the least of these anthropomorphically generated threats to the stability of our planet are the by-products of world energy production. Fossil fuels provide almost four-fifths of the total world energy, and their use continues to grow at a rate of 3 percent annually. In North America, the Great Depression and two world wars reduced this amount somewhat, and the 1973 oil embargo reversed the trend significantly; however, since the mid-1980s emissions have been increasing. Reversing this trend and moving the world gradually away from this massive dependence on fossil fuels or at least dealing successfully with harmful emissions is essential to stabilizing the climate.

As a responsible power producer committed to a sustainable environment, the Corporation is acutely aware of its responsibilities in these areas. However, the problem must be clearly defined. Initial studies of the greenhouse effect have shown that identified changes have considerable uncertainty.

The Corporation, in an effort to resolve some of these uncertainties for Ontario, has been involved for some time in monitoring global programs. These programs have generated data, but many have properties that preclude the use of existing techniques of statistical analysis. Recognizing the need to develop methods that would result in the proper analysis of "noisy" data, the Research Division is currently developing trend analyses and prediction techniques with a view to identifying with greater certainty the emergence of any long-term trends in climate. These techniques when applied will allow detection and quantification of changes in temperature and precipitation across Ontario.

Global warming would have profound implications not only for the world as we know it, but also, on a much smaller scale, for its impact on Ontario Hydro's ability to do business. On the supply side, the availability of hydraulic generation could be either jeopardized or enhanced if patterns of precipitation and evapotranspiration were to be altered. Secondly, if further regulations were imposed to reduce greenhouse gas emissions, the fossil generation option would be further compromised. On the demand side, severe climatic changes could switch the peak demand from winter to summer. Another most significant impact would be that conventional future planning tools, which rely on historical climatic data, would become less reliable.



The Research Division's work on global warming to date is not painting as bleak a picture as might have been anticipated. The work to collect, to apply newly developed statistical techniques, and to compare this new data with approximately 100 years of global daily data is well underway. The comparison data are being obtained by Ontario Hydro's Power Systems Operation Division from the databases of the Canadian Atmospheric Environment Service. Another basis for comparison will be the data from the NASA Goddard Space Flight Center, which includes data from Russian records. In the global perspective, these data will allow comparisons that will contribute to the testing of scenarios obtained from simulations against real data.

The area being studied by the Research Division is bounded approximately by the 43° to 67° parallels, but emphasizes the area serviced by Ontario Hydro. This area is enough to determine if the magnitude of greenhouse-induced change is increasing with latitude, as predicted by global models. Examination of the data reveals that a slight increase of average yearly temperatures has occurred during the last decade. Warming increases with latitude and is of significance only in the northwestern portion of the province, where there are indications of earlier springs.

Options to resolve problems associated with burning fossil fuels include the reduction of coal use, reduction of sulphur levels in coals, and the installation of emission control equipment.

Award-winning SONOX technology developed at the Research Division has resulted in an agreement with a major U.S. air pollution control firm that allows Ontario Hydro exclusive worldwide marketing rights.

Additionally, the timing of precipitation occurrences has shifted. Winter precipitation has decreased, and this coupled with earlier springs and warmer winters is expected to impact on the pattern of spring runoff. Once the obtained data have been thoroughly analyzed, concentration will shift to quantification of the implications of the data for hydraulic generation and electricity demand.

It has already been noted that one of the undesirable effects of burning fossil fuels is that the process adds to the concentration of greenhouse gases in the atmosphere. Burning fossil fuels also adds sulphur dioxide and nitrogen oxides to the atmosphere, which, in turn, contributes to a further environmental problem — the production of acid rain. In an effort to sustain the environmental base, Ontario Hydro is heavily committed to a comprehensive program to address this wide-ranging and complicated problem.

A number of approaches to problems associated with burning fossil fuels are being pursued by Ontario Hydro. The conversion of fossil fuels into a cleaner product is one of these. The development of an integrated gasification combined cycle turbine (IGCC) allows the use of lower cost coal rather than gas as a primary fuel. The IGCC conversion process integrates several proven processes, such as combined cycle and coal gasification, into a single high-efficiency, cleaner fossil option. Other options include the reduction of coal use, the reduction of sulphur levels in fuels, and the installation of emission control equipment.

A limestone slurry system will be installed on two units at Lambton TGS with an in-service date of 1994, and depending on load growth, more flue gas desulphurization systems will be installed at both Lambton and Nanticoke TGSs. A post-combustion acid gas emission control program designed to optimize high-efficiency scrubbing systems is underway. Results to date show that a limestone dual alkali process should perform as designed and that the production of commercial gypsum is technically feasible.

Another recent development is the SONOX process. This process uses a lime or limestone slurry with a nitrogen-based additive that allows the simultaneous removal of SO_2 and NO_x in one step. The slurry is injected directly into a furnace at temperatures between 900 and 1200°C. The technology achieves up to 85 percent SO_2 removal and effective NO_x removal of 63 to 80 percent. In some situations, the cost of installing and operating a SONOX can be as low as 50 percent of the cost of installing a wet flue gas desulphurization system. The technology won a New Business Ventures Excellence Award in 1989, and a major U.S. air pollution control firm has entered into an agreement with Ontario Hydro to establish exclusive worldwide marketing rights.

In the atmosphere, NO_x reacts with volatile organic compounds (VOCs) under action of sunlight to produce ozone and other photo-oxidants. Under specific weather conditions, photo-oxidants can reach levels thought to be harmful to human health, crops, and forests. The unusually hot and sunny summer of 1988 was conducive to photo-oxidant formation and ozone levels were at their highest in recent memory.

Whereas it is well known that ozone concentrations in the lower atmosphere depend on prevailing NO_x and VOC concentrations, the exact mechanism is complex and not fully understood. Southern Ontario is subject to some of the highest ozone concentrations in Canada. It is also known that the region is subjected to significant transboundary fluxes of ozone and its precursors. Additionally, a large number of sources, both natural and anthropogenic, are involved. At this time, it is difficult to specify with any certainty how ozone concentrations will respond to changes in NO_x emissions.

The Research Division has put into place a program, NO_x Emissions and Ozone Formation, which will generate information about Ontario Hydro's impact on ozone production. The work complements that being done in the U.K., Europe, the U.S., and by the Canadian federal and provincial governments and universities. Components of this program include an analysis of air quality; measurements of VOC concentrations, particularly of natural VOCs in air; measurement of NO_x emissions from soils; and modelling of the formation of ozone and other photo-oxidants in background air and power plant plumes.

Since the program started, achievements have been considerable. The concentrations of VOCs in air samples collected by Ontario Hydro have been determined in collaboration with Environment Canada, the Ontario Ministry of the Environment, and York University. A tethered balloon technique that can measure the vertical profiles of VOCs in the lower atmosphere has been developed. A method of measuring NO_x emissions from soils in situ is in use and is being compared with an alternate method developed for the laboratory. This allows a cheaper and more convenient means of measuring NO_x emissions from a wide range of soils.

Additionally, a photochemical box model is being used to interpret an extensive set of field measurements of VOCs made in Southern Ontario. Modelling indicates that natural VOCs play a significant role in local ozone formation. The work will help assess the role of Hydro's current operations.

Overall, what the Research Division is learning is that innovation must be considered a product to be marketed like any other. In a ruthlessly competitive technologically oriented global market, new technology is of little use unless it creates value. It is not only the senior manager, but also the researcher who must see how firmly wedded is the world of technology to the world of business. The inherent value of each to the other is high. Ontario Hydro's researchers are listening to senior management and responding to its questions: "How are the Corporation's needs changing?" "Where should we focus our resources?" "How can this discovery be turned to Corporate advantage?" "How can the gap between laboratory discovery and commercial implementation be shortened?" "What's out there in the scientific community that could help?" Only when the thrust of R&D is to answer these questions can laboratory discovery be linked to a company's overall mandate. Research and development are the levers. The strategies that can turn the best technology to Corporate advantage are dependent on management's attention and control.

Canada's harsh climate, always a challenge that must be met, has given rise to a study of the complex subject of ice forces on dams.

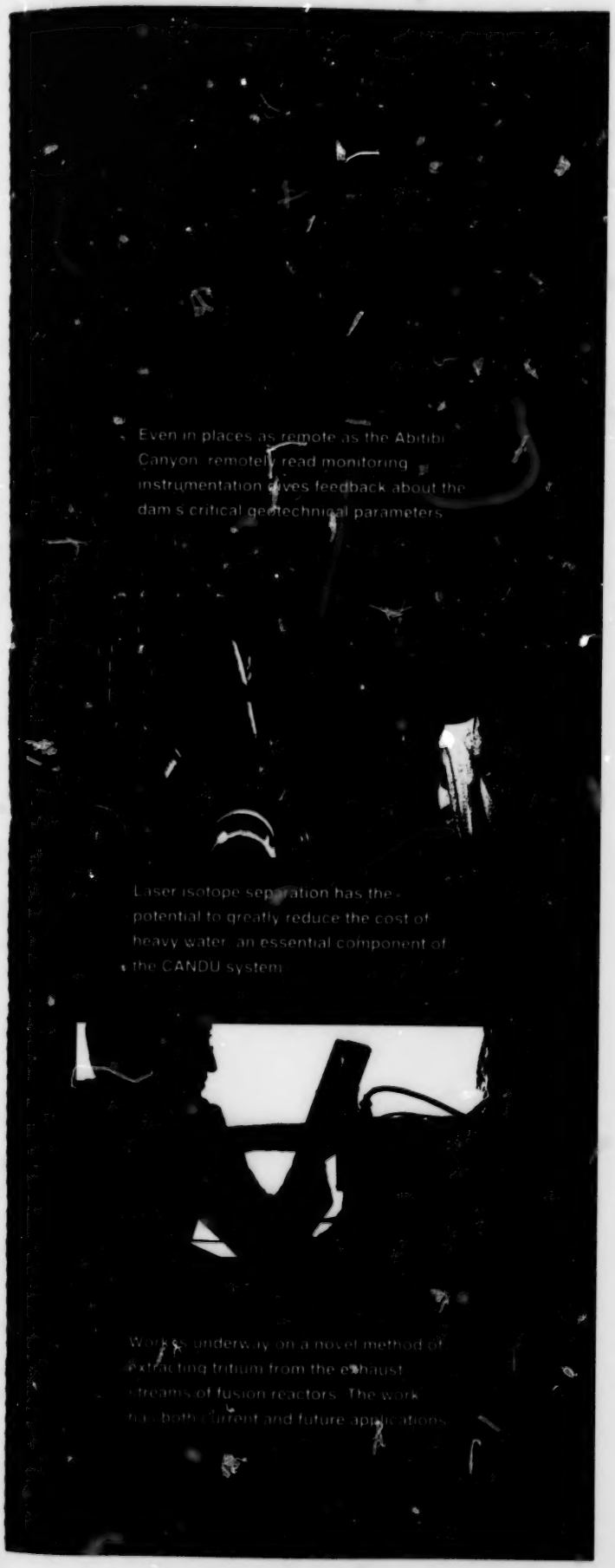
Ontario Hydro's generating stations are of three types: hydraulic, fossil, and nuclear. Fossil stations produce heat by burning either coal, oil, or natural gas. Nuclear stations use natural uranium in the CANDU reactor to generate heat. Both fossil and nuclear stations use the generated heat to produce steam, which in turn drives turbines. The remaining option, hydraulic, uses Ontario's water resources. The public does not always understand that, although Ontario has extensive water resources, not much of this water has enough drop or flow to make it suitable for hydraulic development. As it stands now, Ontario Hydro produces nearly four times as much electricity from sources other than hydraulic, and further hydraulic development, although a high Corporate priority, is necessarily limited.

During their 90-year lifespan, hydraulic stations require major repair. The Civil Research Department contributes to the life extension of aging hydraulic stations through the Corporate Dam Structure and Turbine Upgrading Program, which provides state-of-the-art technological support to evaluate the integrity and to monitor the performance of Hydro's hydraulic stations. Programs run the gamut of the Civil discipline. One project improves dam safety by installing automated, remotely read instrumentation that can monitor critical geotechnical parameters in places as remote as the Abitibi Canyon. Another project seeks to determine the dynamic properties of foundation soils under conditions of seismic loading. Additionally, advanced monitoring systems were installed at Lower Notch GS and Manitou Falls GS to provide advance warning of abnormal behaviour attributable to dam deformation. Canada's harsh climate, always a challenge that must be met, has given rise to a close study of the complex subject of ice forces on dams and, over the past few years, to the development of polymer-based organic materials now used in transmission line foundation construction at subfreezing temperatures.

The Mechanical Research Department is also involved in the turbine upgrading program. To establish their structural integrity, turbine runners from six generating stations are being tested at twice their usual operating speed. The in-service dates of these runners ranged from 1904 to 1924. Additionally, a collaborative project being undertaken with the Canadian Electrical Association (CEA) will result in the provision of guidelines to Operations Branch on how to avoid bearing failures in hydraulic turbine generators.

The reliability of generators in Ontario Hydro's fossil-fired stations must be assured. Outage and repair costs can be enormous and can sometimes be avoided. Avoidable costs are incurred when a generator is either taken out of service because of a suspected problem that does not materialize or left in service with an unsuspected problem that subsequently leads to failure. To avoid these types of failures, the Research Division developed the generator expert monitoring system (GEMS), which is designed to help operators diagnose problems as they develop. The system was developed at the Research Division with funding from the Electric Power Research Institute (EPRI) and in cooperation with Design and Development-Generation Division, Nanticoke TGS, and SRI International. A GEMS prototype system, already in operation at Nanticoke TGS, is expected to prevent costly failures.

Another problem impacting on station reliability is attributable to minute breakdowns (partial discharges) within insulation systems. Partial discharges are symptomatic of aging and may be harbingers of a system's eventual failure. Only the most advanced instrumentation can distinguish these very weak signals, which might last only a nanosecond, from the high noise background typical of generating stations.



Even in places as remote as the Abitibi Canyon, remotely read monitoring instrumentation gives feedback about the dam's critical geotechnical parameters.

Laser isotope separation has the potential to greatly reduce the cost of heavy water, an essential component of the CANDU system.

Work is underway on a novel method of extracting tritium from the exhaust streams of fusion reactors. The work has both current and future applications.

State-of-the-art instrumentation, developed at the Division, has been in use for several years in hydraulic generators and has saved the Corporation many millions of dollars in avoided outage and repair costs. A comparable system for thermal station turbogenerators is in an advanced state of development, and prototype systems have been installed in three thermal stations. Additionally, partial discharge diagnostics is becoming increasingly important in relation to substation switchgear reliability.

Metallurgical Research Department's support of thermal generation is concerned primarily with life extension. This year's work involved the rehabilitation of Lakeview Units 5 and 6. In situ metallurgical evaluation was applied to determine the residual life of high-energy piping. Mechanical Research was also involved in this life extension program, and studies carried out at Lakeview TGS included an investigation of piping integrity, the development of systems designed for on-line monitoring of components, and the development of boiler tube assessment models. Additionally, extensive analytical work to determine the cause of failure of turbine blades at Nanticoke TGS has been completed. As a result, recommendations for modifying the design of these blades have been made.

Like other types of power plants, nuclear stations are susceptible to aging. Securing the high performance and safe operation of Ontario's nuclear stations is of paramount importance to Ontario Hydro's reliable and economic operation. Assurance of nuclear plant performance by means of nondestructive inspection techniques demands a comprehensive multidisciplinary approach; a heavy reliance on computer technology, signal processing, and electromechanical design is required to advance the sophistication of acoustic emission, eddy currents, ultrasonics, and spatial measurements technologies.

High technology applications of electromagnetics have provided short-term responses to problems occurring in operating reactors.

At this time, the Research Division is heavily involved in assuring CANDU fuel channel performance. Pressure tube studies include several projects designed to increase understanding of degradation mechanisms. Some of these are described at length in the earlier article "Leadership Through Innovation". Other programs involve making life assessments that allow informed decisions regarding fuel channel rehabilitation programs. This latter area of endeavour includes enhancement of the pressure tube creep deformation code, modelling of pressure tube hydride blister growth, and analysis of residual stresses in pressure tube rolled joints. The work on blister growth requires a detailed understanding of the sources and ingress routes of deuterium into the pressure tube material.

Studies are in progress to achieve end-of-life conditions in preservice zirconium niobium alloy, the material from which pressure tubes are made. In one program, zirconium niobium alloy is subjected to high neutron flux in reactors. Until recently, these tests were carried out in the DIDO reactor in the U.K. Since the closure of the DIDO reactor, alloy specimens have been transferred to France's OSIRIS reactor where the work continues. Results are providing the basis for ongoing research in many areas of the fuel channel program; changes in alloy microstructure that occur as a result of neutron bombardment can significantly affect the corrosion and fracture properties of pressure tubes, as well as their deformation rates. This type of work enabled the installation of a revised fuel channel creep code, called CDEPTH, to be installed in personal computers in Design & Construction and Production Branches.

Electrical Research Department is also involved in CANDU-related work. High technology applications of electromagnetics have provided short-term responses to problems occurring in operating reactors. The most significant of these applications includes shock heating techniques for separating pressure tube and calandria rolled joints, which were used in the Pickering NGS Unit 1 and 2 retubing projects; the speedy development of an impulse current method to reposition garter springs in reactors; and more recently, the development of an alternating current technology that has enhanced the performance of spacer location and repositioning (SLAR) tooling. Costs avoided through these projects run into the hundreds of millions of dollars.

Experimental, analytical, and failure investigations of components that fail during their operational life comprise an important Research Division activity. This year, the Division provided valuable support when cracks were found in an operating Darlington NGS Unit 2 generator shaft. Metallurgical Research was called upon to conduct an exhaustive metallurgical analysis of one-half of the fracture surface to determine the cause of failure and the mechanism of crack progression. This materials analysis was complemented by a series of tests performed by Mechanical Research to determine cyclic stresses in the replacement rotor. Based on an evaluation of these stresses and an analysis of fatigue properties of the replacement rotor, all other operational rotors at Darlington NGS were modified to reduce areas of high stress concentration. To ensure that any stresses arising from machining and polishing were sufficiently small, a final step involved measuring residual stresses nondestructively by means of an x-ray diffraction technique.

Mechanical Research was also significantly involved when vibration levels of a primary heat transport pumpset exceeded warning and, in some cases, shutdown levels. The Department's timely intervention and provision of an advanced monitoring system enabled Research Division staff to reduce vibration to acceptable levels, thereby preventing a costly unit outage. Loss of power for other than safety reasons could not have been tolerated; at the time, electrical demand for the province had already exceeded system capacity.

Steam generators and other types of heat exchangers are also the focus of much attention in the nuclear generation program. To assure the reliable performance of steam generators, Chemical and Metallurgical Research Departments are gaining further understanding of corrosion mechanisms and providing strategies to prevent or mitigate them. Improving water chemistry, determining corrosion product transport mechanisms, understanding contaminant behaviour, characterizing the corrosion of materials under conditions of atypical water chemistry, such as are found beneath deposits, and defining the optimal water chemistry in preparation for station shutdown are only some facets of the current effort. The expertise gained over many years in the chemical cleaning of steam generators in thermal stations is being used to develop cleaning programs in nuclear plants.

Replacing heat exchangers as a result of corrosion damage involves considerable capital expense. The Chemical Research Department is exploring the role played generally by microbiological action attributable to the use of lakewater cooling methods. However, the recent invasion of the Great Lakes by zebra mussels is further increasing the risk of replacement. Consequent fouling of generator station intakes, heat exchangers, and internal freshwater systems has mandated a comprehensive research program designed to inhibit the organism's growth. A wide range of physical and chemical technologies are under intensive investigation, and research on mussel physiology is being done to provide an understanding of which preventive applications ensure optimal success. In the Civil Research Department, special methods of filtering intake water and subjecting the mussels to pressure are being evaluated for their usefulness. Preliminary laboratory work will be followed by in situ station tests.

This account of the Research Division's effort to help ensure the best performance of Hydro's nuclear generating stations is far from complete. Some safety-related studies should, however, not go unmentioned. Chemical Research is involved in an assessment of the degradation of nonmetallic materials in a service environment. Other safety-related studies added to an understanding of the formation, behaviour, and removal of radioactive aerosols and hydrogen in containment under postulated accident conditions and performance evaluation of respirators, filters, and impregnated charcoal.

Issues impacting on worker safety generate research studies. Before the primary heat transport system of a reactor can be shut down, it must be decontaminated to reduce worker exposure to radiation. With a view to its improvement, the decontamination process is always under constant scrutiny. Chemical Research continues its involvement by developing improved reagent destruction methods and processes for removing peroxide- and oxygen-based antimony. Fundamental work on inhibitor mechanisms continues, as does more specific study of inhibitors for use at Bruce NGS. Additionally, during the scheduled Pickering NGS outage, an inspection of the vacuum building was carried out. An inspection of access ladders, platforms, restraint frames, horizontal lifelines, concrete anchors, and roof seals was conducted. The inspection revealed these components to be in excellent condition, with only a few anchorages and a negative pressure containment line requiring replacement.

Although much progress is being made toward understanding and managing age-related degradation of nuclear plant components, many issues require further understanding and further research and development (R&D). To aid the process, this year an integrated and comprehensive strategic plan on the subject has been prepared for CANDU Owners Group.

Polymer-based organic materials have been successfully developed and applied in transmission line foundation construction at subfreezing temperatures.

Hydro delivers the power produced by its 79 generating stations through a province-wide transmission and distribution network. The transmission system includes the transformer stations and other equipment that provide voltage regulation, switching facilities, and equipment protection. The delivery system is designed so that Hydro can manage fluctuations in power demand arising from adverse weather conditions, emergencies, and other unusual conditions.

Several interdisciplinary research programs support the upgrading of existing lines and stations. The Corporation's overhead transmission line refurbishment program has high priority. Over 27 000 circuit-km of transmission lines service the province. To ensure reliability, these lines, some of which have been in service since 1906, need upgrading. Through the refurbishment program, overhead ground wires are in the process of being systematically replaced through normal maintenance, and hardware and insulators are to be renewed. Aging towers, conductors, and concrete footings are additional components of the system that Research Division staff are assessing as part of the refurbishment program. Key achievements of this program are successful full-scale testing of towers in the field and the adaptation of a conductor corrosion device on lines up to 230 kV.

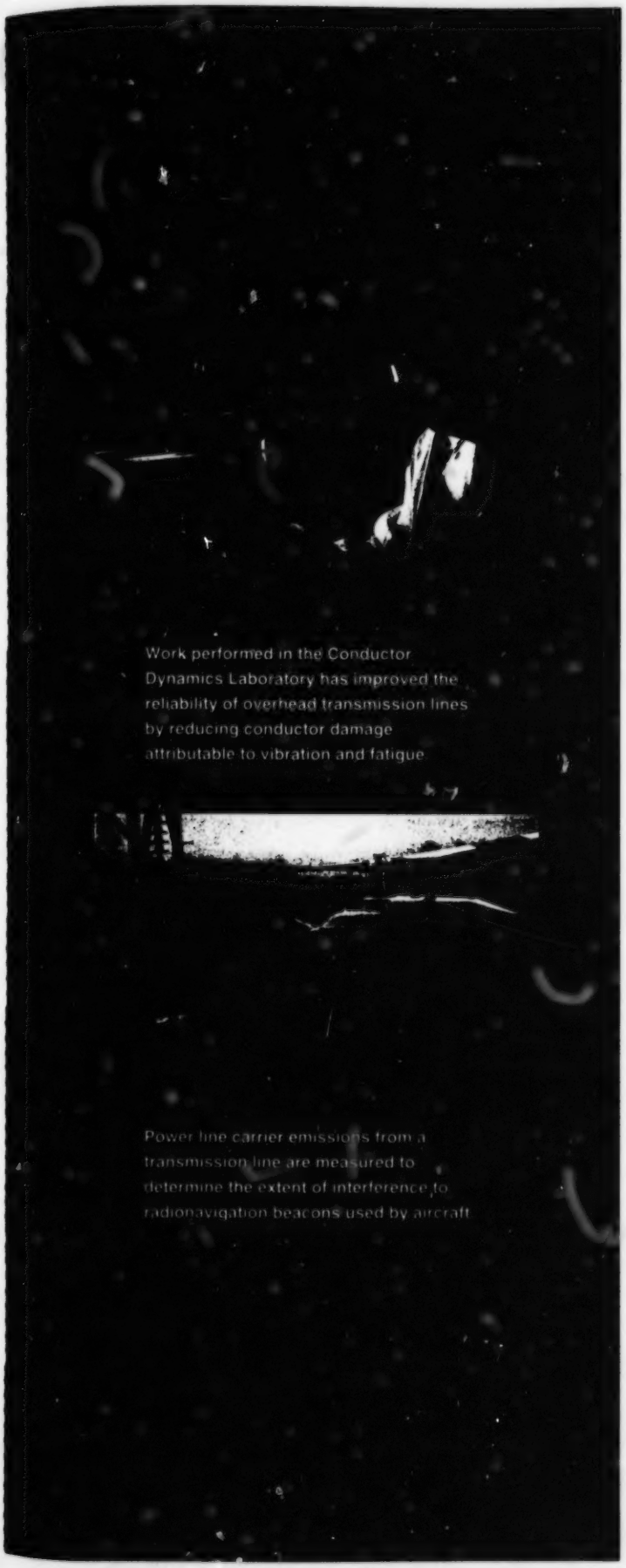
The definition phase of studies to determine the potential for refurbishment of older overhead transmission lines and their components is complete. New data were provided on the useful lives of foundations, towers, hardware, and conductors. Line refurbishment is found to be primarily dependent on conductor condition, since other components can be maintained or replaced, many without interrupting service. The average life of a conductor is approximately 65 years, considerable differences being evidenced in clean versus polluted regions. A plan to begin refurbishment has been approved.

A refurbishment rate of 400 circuit-km per year is necessary to eliminate conductors that exceed their forecast service life by the year 2010. Some lines requiring refurbishment are on narrow rights-of-way, which means the use of round stranded conductors would violate design practice. As a response, trapezoidal stranded conductors are being investigated to assess their reduced drag—and the corresponding reduced wind swing—which may allow their use on narrow rights-of-way.

Atmospheric processes directly affect the reliability and service life of equipment. Transmission line corrosion, particularly of conductors and towers, caused by airborne corrosive gases and aerosols, are studied in the Chemical Research Department with a view to developing a pollution climatology index and an environmental corrosion index, both of which could be used when planning refurbishment. Work continues on developing techniques to monitor and forecast the critical atmospheric conditions that lead to insulator flashovers on 500-kV lines during freezing rain and fog.

Reliable underground cabling is essential to a reliable delivery system. Reliability is affected by the degradation of polymeric cable insulation materials. The Chemical Research Department is establishing the mechanisms of polymer degradation and developing methods to assess their impact on service life. Civil Research is investigating the condition of thermal backfills in which old transmission cables are operating in Metropolitan Toronto. These projects will assist in planning the replacement or upgrading of aging cables and help ensure efficient operation.

Polymer-based organic materials have been successfully developed and applied in transmission line foundation construction at subfreezing temperatures. Because of costs, these materials are restricted to special applications. However, an attempt is being made to develop a modified cement-based material that will set, cure, and achieve full strength at low temperatures without the need for winter precautions.



Work performed in the Conductor Dynamics Laboratory has improved the reliability of overhead transmission lines by reducing conductor damage attributable to vibration and fatigue

Power line carrier emissions from a transmission line are measured to determine the extent of interference to radionavigation beacons used by aircraft

Metallurgical research is studying the benefits that may be reaped from the use of conductors with improved creep properties. Such conductors could eliminate the steel core required in currently used conductors. A program to establish the creep properties of aluminum alloys and to determine whether these properties can be improved through modification of their metallurgical structure is in progress. Line hardware performance could also be improved with the use of better materials; for these applications, metal matrix composites look attractive. A collaborative program with the Canada Centre for Mineral and Energy Technology (CANMET) is in place, the objective of which is to develop components with superior properties.

Adverse weather conditions also wreak havoc on overhead transmission wires. Fibre-optic cored overhead ground wires (OPGW) are now being installed on all new transmission lines to build up a communications capability across the province. Designs of support hardware and different OPGW constructions are being subjected to fatigue cycles, i.e., simulated aeolian vibration due to wind, to provide assurance of their long-term reliability.

The transmission research program comprises only one-half of Ontario Hydro's delivery program. Distribution research, the other side of the delivery coin, is focused primarily on the development of techniques to improve safety and reliability of the power system delivery network.

A major portion of the delivery system consists of intricate distribution networks and the municipal utilities in the province. Since most power outages are caused by network failures (operating at voltages up to 27 000 V), a substantial effort has been devoted to distribution reliability and maintenance safety. As a result, the requirements for high-voltage fuses can be reduced by applying better fuse coordination guidelines. This change ultimately translates into savings of more than $1 million per year for the Ontario Hydro retail system alone. In addition, in situ transformer tests now under development will reduce the risk of transformer failure.

A major concern in the distribution research area is the effect of Ontario's often adverse weather conditions on power delivery. The delivery of power from generating stations to customers involves the use of a system that has to maintain reliable service in a hostile environment. This is generally taken for granted, but depends on the development of many technologies fundamental to a secure system. For example, the vibration of lines caused by wind and ice accumulation manifests in many forms, most of which cause fatigue damage to the conductor as well as other forms of damage to hardware and structures. Field trials of devices to control galloping of distribution lines and bundle conductor transmission lines are continuing in Ontario and in other provinces under the auspices of a Canadian Electrical Association (CEA) program. To date, results show that galloping amplitudes on several classes of line can be reduced 70 to 80 percent by the addition of detuning pendulums.

The effects of lightning on the system are being studied to determine how best to cope with the hazards lightning creates. Additional sites have been selected to improve the efficiency of Ontario Hydro's severe weather forecast and detection system (SWORD). This advanced system provides data that enables power system operators to make informed decisions about high-risk areas and to minimize allocation of the replacement energy required to ensure reliable system operation during storms. To that same end, 50 feeder event recorders and two station event recorder systems have been developed and installed to provide data on the effects of lightning on distribution systems. This work will lead to better distribution equipment and standards, making it cheaper and easier to deal with lightning problems and to provide better distribution reliability.

The need for power system protection cannot be overstated. In the Electrical Research Department, a major innovation known as the programmable auxiliary logic controller/analog input module (PALC/AIM) system is a "universal" protection device that combines extreme versatility with ease of installation and application. Approximately 200 of these devices have already been installed. This move toward a new standardized approach to power system protection also lowers the cost of specifying, designing, and maintaining protection systems. In addition to providing new protection systems, devices have also been developed for monitoring and control.

Eight power system disturbance recorders have been installed across Ontario to provide accurate monitoring of power system conditions following disturbances such as the sudden loss of a large generator. This information is crucial to enable system planners to specify the highest permitted operating limits possible without jeopardizing system stability. As well, the programmable synchrocheck relay adapted the synchronizing criteria to system operating conditions. The relay is an intelligent adaptive device that performs the "synchrocheck" function in transformer stations that have a variety of changeable configurations.

The application of power system stabilizers to advanced digital excitation systems, purchased for power plant life extension, and improvements in the tuning of existing power system stability controls have helped to relieve system operating constraints. Enhanced protection of power system components has contributed to unit availability. An in-depth analysis of the surge protection of generators is being carried out by Electrical Research under an Electric Power Research Institute (EPRI) contract. The analysis has provided a firm basis for selection of the most economical and effective surge protection schemes. At the same time, models developed for generators, transformers, and other system components have allowed computer programs used for system security assessment to be more precise, thereby improving our ability to maximize capability of the existing system without sacrificing system security.

By transferring technology to customers, the Research Division ensures that electrical efficiency improvements are realized as quickly as possible in the marketplace.

With seemingly endless discoveries of new applications for electricity, the public demand for energy continues to grow. Ontario Hydro is faced with the omnipresent threat of demand exceeding supply. Despite this pressure, the building of new facilities is being deferred while older facilities are being restored. Other strategies, however, exist to bring power demand in line with realistic supply options; one such strategy is Ontario Hydro's demand management program, which is designed to help customers use less electricity more efficiently.

The Research Division's Utilization Program is part of the Corporation's demand management strategy. By supporting the development of Energy Management Branch (EMB) programs and by transferring technology to customers, the Research Division ensures that electrical efficiency improvements are realized as quickly as possible in the marketplace.

In the past 2 years, EMB has launched a number of demand management programs based on the developments of the Research Division. Electrically efficient heat pump technology has been a high profile mandate for both the Research Division and the Corporation; space heating and cooling account for approximately 34 percent of electricity use in the residential sector. Development and field testing of the burner-assisted heat pump, undertaken by the Division in cooperation with its manufacturer, revealed the benefits inherent in this unique system. Quickly making use of Research Division's efforts, the Corporation advocated the transfer of the heat pump to its residential customers by offering a Corporate subsidy twice the amount of that offered for any other air source heat pump. Similarly, Ontario Hydro's promotion of ground source heat pumps resulted from province-wide field testing conducted by the Research Division. Ground source heat pump technology continues to advance; the pump's heat extraction and delivery system is being refined with the help of Civil Research's expert understanding of the ground's thermomechanical response. In support of the program, a further study is being done for the Canadian Earth Energy Association. The study is exploring the phenomenon of ground ice formation, which could interfere with efficient operation of the pump.

The Research Division's Utilization Program contributions are by no means limited to heat pump technology. Research and development in the areas of water heating, building heat loss reduction, and appliance technology can result in extensive energy savings; consequently, this work has featured in the development of numerous demand management programs aimed specifically at the residential sector. For example, laboratory evaluation of the effects of insulation blankets and showerheads formed the technical basis for Ontario Hydro's recent "Water Heater Tune-Up" and "April Showers" promotions. Other EMB programs and pilots that have received considerable assistance from the Research Division include the window retrofit and basement upgrade programs, the "1000 House Study", and the "Laundering for Less" campaign.

Since 1982, over 130 companies have been involved in EMB's "Research Assistance Program", which transfers Research Division technology and provides technical support to Ontario industry. Ivex Industries is one satisfied customer; the company now employs infrared preheating of plastic film, a low capital cost retrofit that increased productivity by 25 percent and obviated the need for an expensive new production facility. In addition, the installation of a heat recovery heat pump at Casco Industries resulted in reduced energy consumption (equivalent to savings of $64 000 per year) and merited a Canadian Electrical Association (CEA) energy efficiency award. Because recent statistics indicate that motors accounted for 73 percent of the industrial sector's electricity consumption, Hydro is targeting the promotion of high-efficiency and variable-speed motors and drives. To that end, a prototype portable motor-efficiency measurement system was developed by Mechanical Research specifically for EMB.

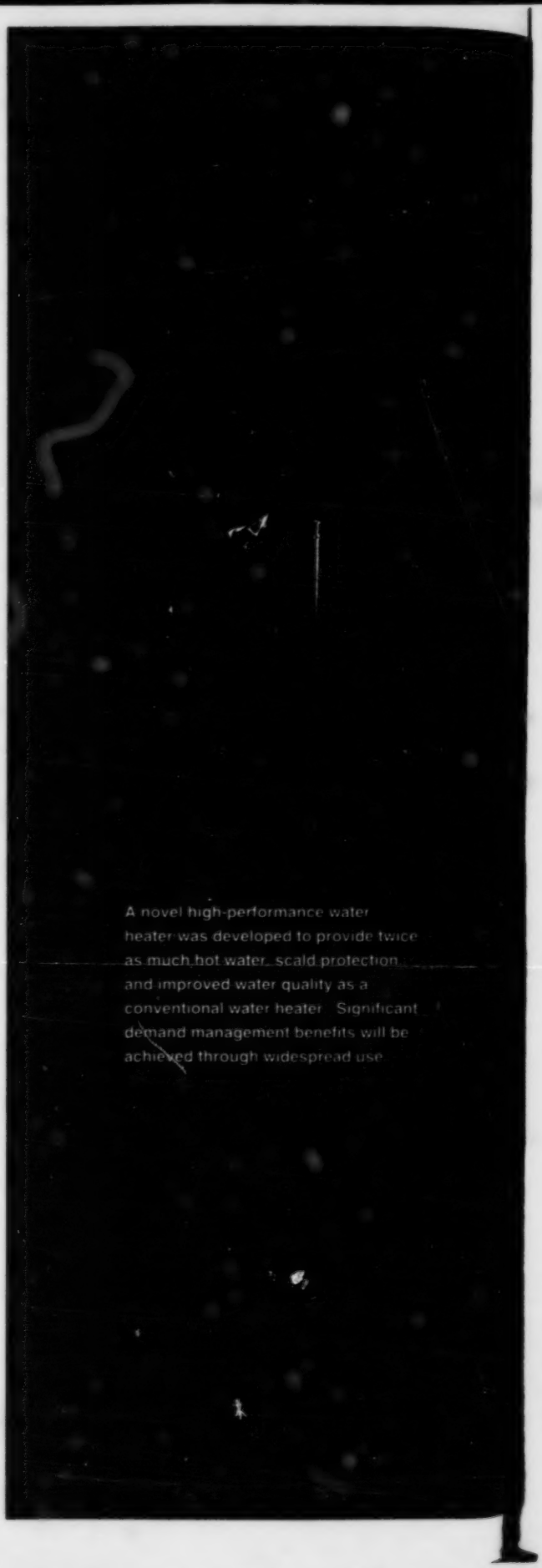
Past successes in the industrial "Research Assistance Program" guarantee a continued demand for research and development of energy-efficient technologies. Currently being investigated is the application of laser welding of copper in the computer industry.

The recent efforts of the Chemical Research Department have centred on an electrochemical testing and development facility (ETDF) commissioned this year. The facility is used to develop processes and to test electrodes on scales that will permit direct comparisons of commercial scale operations. The ETDF also evaluates chemical unit operations that industries could use to reduce electricity consumption.

It is a simple but accurate equation: efficient utilization of electricity directly translates into benefits to the environment. For example, a successful demand management program will reduce the consumption of fuels that can be harmful to the environment. This equation has been tested and proven by the recent work done at the Division. In an effort to improve the productivity of the metals- and minerals-producing industry, a process metallurgy project was initiated 3 years ago. The centrepiece of the project is a flexible electric furnace facility that, when used in collaboration with industry, optimizes electrical energy efficiency in metallurgical processes. Carried out with Falconbridge Limited, the first project involved developing an energy-efficient smelting method that ensured the compliance of Falconbridge's sulphur dioxide emissions with provincial government guidelines.

Work in the area of microwave technology continues. Commercial microwave equipment, boasting both high efficiency and lower maintenance costs, continues to be introduced to Ontario industry. The transfer of efficient microwave technology to industry is also advantageous to the environment; for example, microwave regeneration of activated charcoal allows the dry cleaning industry to recycle filters rather than consign them to landfill.

When demand and supply diverge, Ontario Hydro is faced with two options: creating more supply or reducing demand. The Research Division is strongly supporting the latter option and helping to reduce the effect of Hydro's operation on the environment, a contribution that cannot be minimized.



A novel high-performance water heater was developed to provide twice as much hot water, scald protection and improved water quality as a conventional water heater. Significant demand management benefits will be achieved through widespread use.

In the area of environmental research and development (R&D), the Division supports Corporate efforts to assess the impact of its current and planned activities and to control emissions and wastes by the provision of new scientific knowledge and technologies. Additionally, technical support is given to different parts of the Corporation to allow the fulfillment of specific environmental goals. In 1990, a major activity was a review and a reorientation of the Division's research program on environmental impacts to ensure that issues of pressing public concern were being appropriately addressed.

There has been a steady and significant increase in public and government awareness of environmental concerns, particularly as they relate to human health. It is vital that Ontario Hydro test the truth of the assumption that exposure to electromagnetic fields is safe. Public concern has turned this into a major issue that impacts on Hydro's ability to construct new power lines. As a response, the Corporation has initiated an Electric and Magnetic Fields Risk Assessment Program (EMFRAP), which is determining the effects, if any, of public and occupational exposure to low-frequency magnetic fields. In addition to participating in the EMFRAP, the Chemical and Electrical Research Departments have initiated a long-term program in cooperation with academic institutions to investigate the interactions of electric and magnetic fields with biological systems and the biological responses of these fields. The objective is to gain the fundamental information needed to resolve the issue.

A recently completed rodent study showed no harmful effects of magnetic fields from computer screens, thereby casting serious doubts on earlier reports from Europe. Co-funded with IBM and carried out with the University of Toronto, this extensive study made use of special exposure facilities developed at the Research Division. The collaborative project and subsequent power-frequency research have contributed much to the Corporation's credibility in approaching the issue of public concern about the effects of magnetic and electric fields.

Environmental assessment (EA) requires would-be users of the ecosystem to assure the public that their proposals will not adversely affect the interests of future generations. The environmental effects of constructing and operating a generating facility are many. The Research Division is working to improve the ability of the EA process to protect the environment by providing better tools and more detailed knowledge with which to carry out the evaluation.

For example, current work involving radiotelemetry and sonar techniques can improve the efficiency of field studies on fish movement and population dynamics. Ways of studying the cumulative and cascading environmental effects of multiple hydraulic stations on river systems are being investigated; once understood, these effects can be prevented or mitigated.

Other research focuses on those contaminants principally associated with Ontario Hydro's activities. Research into oxidation rates of elemental tritium in the environment, uptake of radiocesium by fish, verification of atmospheric dispersion models, the role of NO_x emissions in regional ozone concentrations, and pollutant migration through soils are all examples of work in this area. Results are used in planning new facilities, developing operating strategies, and responding to and complying with government regulations; they also provide early indications of areas in which further R&D is needed for development of control technologies.

Chemicals used by the Corporation are a concern. The Corporation's goal of eventual elimination of herbicide use has significant ramifications for vegetation control on transmission and distribution rights-of-way. R&D is seeking alternatives to the expensive and hazardous manual and mechanical cutting techniques currently in use, with most effort being focused on the concept of natural "cover crops" that retard invasion of woody growth. In a related project, the environmental risk of the effective wood preservative pentachlorophenol is being assessed. A joint effort with universities is concentrating on the development of a leaching and biodegradation process for the disposal of penta-preserved poles.

Management of PCBs is being tackled head on at the Research Division, and compliance with Ministry of the Environment regulations can now be ensured.

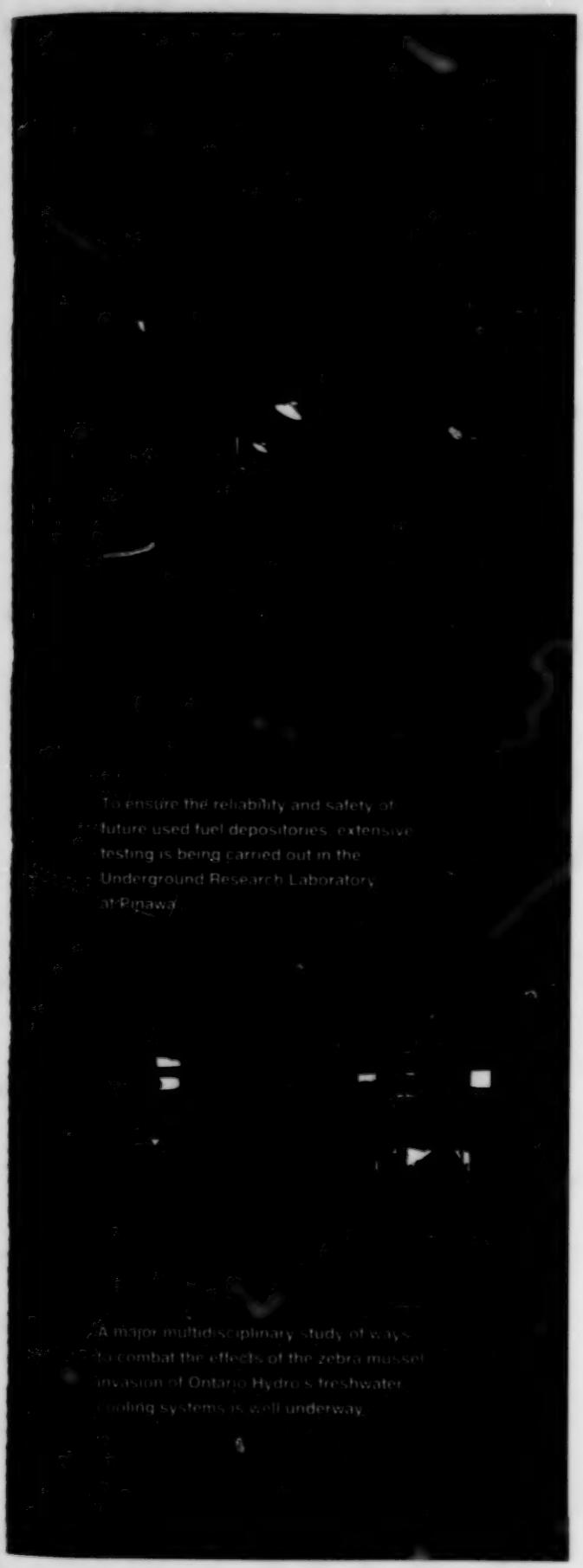
Another unwanted by-product of power generation that has direct environmental effects is the audible noise produced by large station transformers and implosive conductor connectors. To ensure that environmental criteria governing sound emission levels are met, sound levels are monitored and, where appropriate, effective and economical sound-proof enclosures are being designed.

The Chemical Research Department is involved in the reduction of SO_2 and NO_x emissions. It reviews the limestone dual alkali (LSDA) absorber design and investigates the chemistry of the limestone regeneration process in a mini-pilot plant. Additionally, NO_x control and gypsum production from the limestone slurry and LSDA processes are being studied. Chemical Research also provides assistance for a planned demonstration of NO_x control through urea injection. Control of NO_x by means of reburning or staged combustion is also under evaluation for the Canadian Electrical Association (CEA). Meanwhile, the SONOX process that was developed by the Chemical Research Department has been accepted by Research-Cottrell for commercialization. The company is planning a number of full-scale demonstrations.

Management of PCBs is being tackled head-on by the Research Division. The Corporate PCB Destruction Task Force is chaired within the Chemical Research Department; the strategy developed includes a major research program on chemical destruction processes. Other work includes support and advice regarding a Corporate demonstration of capacitor retrofilling, on-site monitoring of out-of-province PCB incineration tests, and development of a better on-site PCB analysis technique. Compliance with Ministry of the Environment regulations can be ensured.

Due to increasingly stringent requirements for Ontario Hydro's coal ash disposal, the Civil Research Department is exploring economical and environmentally preferred techniques for ash management. Efforts include laboratory and field testing, as well as computer modelling. Static and dynamic leaching methods were developed for testing of fly ash from the Lambton and Nanticoke TGSs in order to ensure that no groundwater contamination occurs at these fly ash disposal sites. In an ongoing project, Ontario Hydro has successfully used large volumes of fly ash in structural fills, highway embankments, road base backfills, and land reclamation. In addition, the ash has been used for cement replacement in concrete and in the manufacture of cement and concrete products. The Civil Research Department continues to search for innovative fly ash utilization options.

Because nuclear generation will be an important supply option in the next century, nuclear waste is a significant public concern. The Civil Research Department has collaborated with the Mechanical Research Department in the development of the dry storage container (DSC) for the proposed irradiated fuel management system. The container, which has been designed to isolate irradiated fuel for a minimum of 500 years under conditions anticipated in a disposal vault constructed in plutonic rock, is featured as this year's Significant Research Contribution (see inside back cover). In support of this project, automated container welding and remote nondestructive inspection techniques are concurrently being developed by Metallurgical Research staff. Yet another project is characterizing operating wastes, developing waste volume reduction technologies, and determining waste performance under extended storage conditions.



To ensure the reliability and safety of future used fuel depositories, extensive testing is being carried out in the Underground Research Laboratory at Pinawa.

A major multidisciplinary study of ways to combat the effects of the zebra mussel invasion of Ontario Hydro's freshwater cooling systems is well underway.

Whereas the public is rightly concerned about the effects of Ontario Hydro's operations on the environment, it should also recognize that, on a daily basis, the Corporation must cope with factors within the environment itself that make the reliable delivery of power difficult. For example, a patented "SKRAM fishpulser", an acoustic device developed by Research Division for controlling the movement of fish in the vicinity of generating facilities, is now being manufactured under licence for use by utilities and other organizations. Similarly, a major multidisciplinary study of ways to combat the effects of the zebra mussel invasion of Ontario Hydro's freshwater cooling systems is underway. Recent work shows that thermal and acoustic shock treatments may provide an environmentally friendly defense against the organism.

The harsh effects of climate and weather conditions on the transmission system, which result in degradation and corrosion, must be addressed to ensure reliable supply of energy. Projects that respond to this need are further addressed in the sections on the Delivery and Generation Programs.

The Divisional Projects Department (DPD) provides an interface between Research staff and groups internal and external to the Corporation. New technology initiatives, research management studies, and research business support comprise DPD's major products.

The Research Division seeks to leverage its resources and effectiveness by collaborating with external organizations. As part of this effort, departmental staff involved in new technology exert strong influences on Canadian universities and industrial research and development (R&D). The Division influences external organizations through the acceptance by Research Division staff of adjunct professorships at local universities and memberships on industrial advisory councils, such as the Canadian University-Industry Council for Advanced Ceramics, the Ontario Centre for Materials Research, and the Centre of Excellence in Laser and Lightwave Research. Also, DPD staff sit on Natural Sciences and Engineering Research Council committees and help direct and focus university curricula through council memberships.

To afford the Research Division greater flexibility in carrying out its mandate, Divisional Projects is committed to increasing the base of R&D expertise outside the Corporation. In support of Corporate long-range research, the Department organizes the annual Director's Fund competition and manages the Fund's eight ongoing projects. One Director's Fund program deals with the greenhouse effect and its impact on Ontario. Novel analysis of 100 years of weather data consistently shows that weather patterns have changed only over the past decade.

Divisional Projects looks at new energy technologies and assesses the viability of leading-edge discoveries, such as those relating to fusion and fuel cells. The Department also examines the information the Corporation needs before investing in devices such as large-scale combustion turbines and integrated gasification combined cycle (IGCC) turbines. With Ontario's major metals producers, the Department also plays a role in making energy utilization more effective. This work involves investigating current operations and future plans of metals producers and then evaluating whether these operations could be rendered more energy efficient. The results are collaborative research and paper studies.

A major area of study is looking at using oxygen to increase productivity and using electric arc furnaces for scrap melting. DPD is investigating ways to test and improve the effectiveness of Ontario Hydro's demand management efforts. Studies look at how residential customers perceive demand management options and determine which technologies are most acceptable to these customers.

Divisional Projects coordinates the production of the Research Division's 10-year business plan, which communicates future plans to senior management and provides direction to Divisional staff for detailed work planning. To support the Division's strategy-setting and business-planning activities, technology-forecasting activities are undertaken. Long-range planning forecasts are provided biennially for the strategy-setting and planning process. Forecasts are conducted to explore the probable development of specific technologies. Recent forecasts included assessing the impact of advanced industrial materials and high-temperature superconductors on Ontario Hydro.

One departmental responsibility is to identify opportunities to improve research management. The identification and reporting of "notable accomplishments" falls into this area. Notable accomplishments are R&D projects of significant benefit to the Corporation, to the customers of Ontario Hydro, or to some identifiable third party. Such reports are produced every 5 years and clearly demonstrate that the benefits provided by the Research Division significantly exceed its costs for that 5-year period.

Divisional Projects also carries out the very important Directorate support function, which includes general responsibilities such as assisting the Director with presentations and senior management meetings and, more specifically in 1990, with initiatives such as the modernization of the auditorium.

The Research Division Awards Program is the central means of fostering and rewarding excellence within the Division. DPD calls for nominations, orchestrates the selection process, and arranges the facilities for the presentation ceremony, which is usually held off-site.

Supporting research at local universities allows sharing of their sometimes unique capabilities and also encourages promising scientists to enter industrial research careers.

The Department continues to provide support in the area of external contracts. Activities include acting as liaison with Law and New Business Ventures Divisions; developing contracts and agreements and handling proposal requests; and producing and monitoring financial information. In a similar vein, patents are becoming a most important aspect of the Corporation's business; DPD has taken a leading role on the Patent Advisory Committee, thereby becoming a focal point for information on the patent process for the Division. In support of this external contract function, DPD monitors external publications for contracting opportunities. In addition, it maintains and updates information on the Division's capabilities in a number of externally-based databases.

Staff are also involved in the technical communications field. Perhaps the most important communication is the *Research Division Annual.* Research Publications Office staff write and assemble the text and coordinate the editorial activities, artwork, and printing. Another significant publication is the *Services and Capabilities* brochure, which describes the Division's R&D capabilities. This brochure is used extensively by other branches of Ontario Hydro in support of their marketing activities. The most recent publication, *Focus on R&D*, will be used as a guide for new employees and visitors to the Division. The publication offers a descriptive divisional overview. *Chit Chat*, the divisional newsletter, continues to play an important role in enhancing communication and boosting morale. Desktop publishing capabilities have enhanced the quality and significantly reduced the cost of all publications. These high-calibre communications have won a number of awards from organizations specializing in industrial technical communications. Finally, a report database, which has been under development for some time, is now functional; plans to transfer it to the ICE network have been initiated.

In addition to producing written communications, Divisional Projects is involved in the production of videos that describe the Division's activities. One such video, for visitors and new staff, has been produced this year, and another, which deals with the contribution of Ontario Hydro and the Research Division to the growth of Ontario, is in the early stages of production.

The Divisional Services Department continues to provide excellent service to the Research Division. This year, the services offered included business administration; financial reporting; payroll; records, space, and safety management; printing and clerical services; report production; model shop production; drafting; and photography. Additionally, significant strides have been made in the Integrated Computing Environment (ICE) project.

To enhance its specialized machining and prototyping capabilities, the Model Shop continues to upgrade equipment. From an equipment standpoint, efficient prototyping relies on a quick and accurate measurement capability. Versatile computerized numerical control (CNC) machines significantly help to achieve this end. A CNC milling machine, a CNC lathe, and two servo-positioning precision milling machines now complement standard machinery. The remaining non-numerical control milling machines and lathes are equipped with digital readouts on all axes.

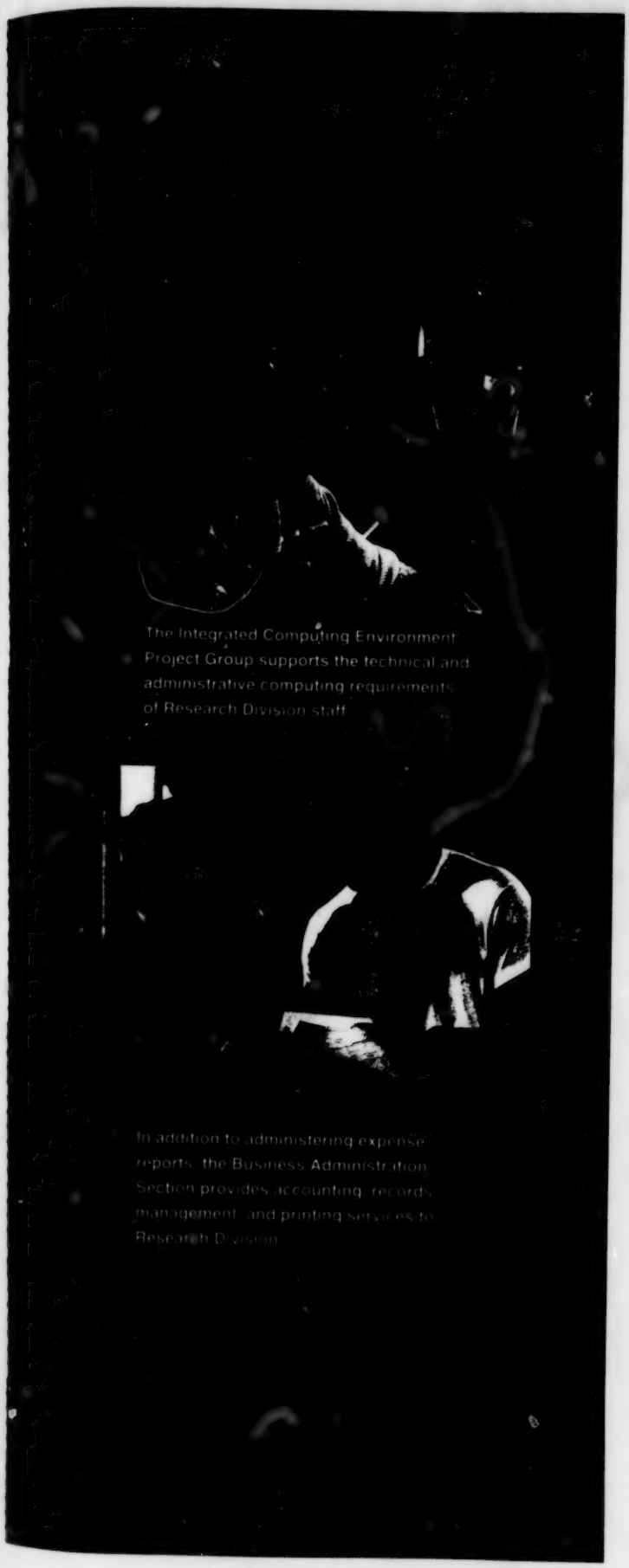
From a design standpoint, shop personnel apply sound engineering practice and materials selection. Much of the Model Shop's work requires meeting the stringent requirements of clients that include CANDU Owners Group, Canadian Electrical Association, and Electric Power Research Institute. When submitting preliminary drawings, the customer has an opportunity to discuss optimized datum referencing, practical geometric dimensioning and tolerancing, and other cost-saving design considerations. Customers are further encouraged to test concepts quickly and imaginatively through simple prototype trials. In this way, clients can investigate isolated design alternatives and more quickly reach a final request with resultant savings on projects.

The ICE Section is responsible for providing computer and communications support to Research Division staff, who now use a site-wide local area network to improve productivity. Specific support areas provided by ICE include technical computing, computer communications, consultation, hardware/software support, and general problem solving. Network services include a central network computer server dedicated to "number crunching" applications, shared disk storage space where commonly required business/technical software applications reside, shared network printers providing report quality output, electronic mail services, and network delivery of commercial, technical, and business database services on compact disk. This array of services promises to evolve to meet future client needs and new business goals. Combined with telephone answering and voice mail services, the ICE network is enhancing Divisional productivity.

The Drafting Section provides the Division with the best in illustration, design, and consultation for reports, presentations, and publications. Consistency, precision, and innovation each play an important role in customer satisfaction, and the office has maintained a high level of service through extensive use of MAC II technology. A TEKTRONIX colour printer has added a new dimension to artwork and visual displays. High-quality technical illustrations and posters, one of which won an achievement award from the Society for Technical Communication, are a hallmark of the Drafting Section.

The Photographic Services Section has had another challenging year. Contributions to major publications included the *1989 Research Annual Report*, the *1989/1990 Canadian Fusion Fuels Technology Program Annual Report*, the *1989 New Business Ventures Annual Report*, the *1989 Report to Employees*, and *Equinox*. Video productions included *Remote Robotic Weld Inspection* (a Research Division production), *Workplace Hazardous Materials Information System* (WHMIS), a video training program (a Research Division production), and *CFFTP - Canadian Fusion Fuels Technology Program* (a CFFTP production). Investigation into a PC-based package that will greatly improve the storage and retrieval of all film and tape images is underway.

The Business Administration Section continues to operate at full capacity, with ongoing and new activities that utilize all staff resources. The Records Management program continues to evolve. In addition to the conversion of administrative files in the Division's various departments to the Corporate General Subject Index, summer students have played a key role in reviewing mountains of inactive files from Central Records. The Accounting Unit inherited additional responsibilities with the decentralization of the accounts receivable/billing activities from Corporate Accounting. The Unit will now be responsible for issuing approximately 500 to 600 invoices per year and for following up to ensure that payment is received.



The Integrated Computing Environment Project Group supports the technical and administrative computing requirements of Research Division staff.

In addition to administering expense reports, the Business Administration Section provides accounting, records management, and printing services to Research Division.

Information Management's commitment to providing secretarial and telecommunications support to the Division is unwavering. The Word Processing Centre provides a relief service by filling secretarial positions in the Division. Additionally, short-term clerical and filing help can be provided as required.

The Health & Safety Section ensures that line management provides a healthy and safe work environment. It also provides guidance to the technical sections on environmental matters relating to laboratory waste disposal, spill control, transportation of dangerous goods, and releases of hazardous substances into the environment. Legislative pressure and Corporate obligations have raised issues related to hazardous material management. Substantial departmental effort was directed at ensuring compliance with WHMIS legislation. To date, all chemicals in the Division have been inventoried and all laboratories have WHMIS boards and supplier material safety data sheets in place, as well as a set of workplace labels prepared for chemical containers. All Research staff have received WHMIS training, and a video-based training program is being completed for future use.

Considerable effort was spent to ensure the Division's compliance with the Corporate Code of Practice on Accident and Incident Reporting. Several incidents with medium and high potential for harm were investigated. Other major activities carried out by the Health & Safety Section were the initiation of hazard identification training, respiratory protection training, and workplace inspections.

Ontario Hydro's complex operation involves management systems and procedures, data and information handling, and equipment and materials. The Operations Research (OR) Department tackles these problems daily with a full range of mathematical and computational methodologies. The Department is one of the most active and effective industrial OR groups in North America.

In 1990, OR's client base and its range of services expanded. Services varied from informal consultations and short presentations to large-scale projects and tailor-made courses and seminars. The Operations & Decision Analysis Section employs sophisticated analytical methods to support Ontario Hydro's generation activities. Recently developed probabilistic performance models allow study of the effect of equipment maintenance on thermal station outage. At the request of Thermal Generation Division, the Section is examining the operating and outage data of coal pulverizers. Failure and downtime distributions are being developed for exploring alternative maintenance strategies. Once tested, the resultant model will be adapted to air and gas systems, generators, turbines, and other equipment.

Mathematical models are employed to improve hydraulic generation efficiency. A model was developed for optimizing the allocation of water to various generating units in hydraulic stations. The model's potential for increasing hydraulic output was demonstrated at the R.H. Saunders GS using historical data. In a simulation study carried out for the month of January 1989, the model produced 641 MWh of additional energy. If applied to all hydraulic stations, the increase in energy production could be substantial. A pilot expert system for improving nuclear fuelling has been completed, and a production version of the system is being contemplated.

All these models and systems may expand energy output at lower costs. Examples include risk analysis in support of turbine blade replacement and decision analysis of alternatives for design and construction management systems.

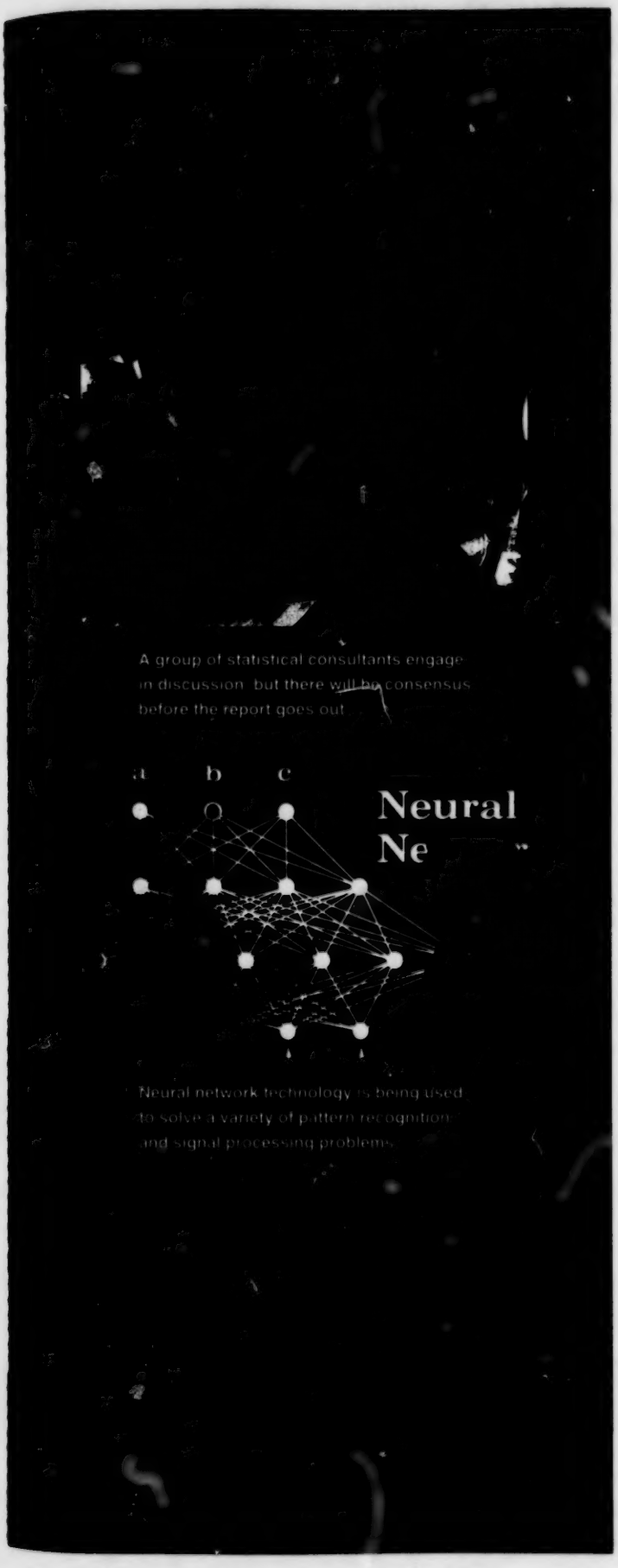
Given the Corporation's need to exercise financial restraint, novel approaches must be applied to enhance management effectiveness. To that end, projects are underway to develop performance indicators for supplying materials to two nuclear generating stations and to creating a manpower planning model for electrical inspection. In addition, Energy Management Branch (EMB) receives analytical support for its demand management mandate. EMB must reduce energy consumption by promoting end-use technology. The Operations & Decision Analysis Section assisted in prioritization and trade-off analysis of EMB programs and developed user-friendly models and databases for the efficient storage, retrieval, and analysis of information.

The environment is a high-profile issue at Ontario Hydro. The Department provides technical support to the environmental program through mathematical modelling and applications of information technology. A computerized emission reporting system has been developed to meet the Ministry of Environment's Municipal and Industrial Strategy for Abatement (MISA) requirements along with models to assess the environmental impact of Hydro's operations.

Accurate reliability predictions for power systems and their constituent parts comprise a most important engineering task. The Reliability Unit is at the forefront of a worldwide effort to develop more advanced tools. Production Branch requested deterministic and stochastic modelling of river inflow forecasts to optimize energy production from hydraulic generating stations. This year an important research project to develop a probabilistic approach to the dynamic stability and security of power systems was initiated. This approach is to be combined with existing techniques to provide a more complete reliability methodology.

Through publications and participation on committees and in conferences, the Reliability Unit enhances its international reputation. This year, staff participated in a number of international activities and served on an Institute of Electrical and Electronics Engineers committee. Members of the Unit provide an advisory function to several Electric Power Research Institute projects.

Selection and analysis of data for technical or management studies often appear straightforward. However, when data are scarce, interrelated, dispersed, or even contradictory, drawing valid conclusions


A group of statistical consultants engage in discussion but there will be consensus before the report goes out
a
b
c
Neural
Ne
Neural network technology is being used to solve a variety of pattern recognition and signal processing problems

requires the advanced statistical analysis offered by the Statistical Methods & Analysis Unit. Studies in 1990 included probabilistic modelling of crack initiation in pressure tubes; analysis of public opinion questionnaires for the Demand/Supply Plan; and comparison of performance indices of system protection devices. Additionally, the Unit assisted Hydro in preparing statistical forecasting models for the Ontario Energy Board hearings.

At the request of the Nuclear Generating Division, the Statistical Methods & Analysis Unit studied the relationship between the operating expenditure and performance of a CANDU reactor. A probabilistic model relating the capability factor (CbF) to operation, maintenance, and administration (OM&A) spending was developed. It was found that reactor aging necessitates higher OM&A spending, and that increasing OM&A spending can improve CbF performance in diminishing increments. This model has been adapted to reactors in the United States and used to help set public utility rates.

Recent advances in computer and information technology, particularly in the areas of artificial intelligence and database management, presented the OR Department with new challenges; in 1990, the Advanced Computational Methods Unit was created to meet these challenges. The Unit is devising a system for the creation, maintenance, and use of hypertext applications. Neural network technology will be used to investigate several pattern recognition and signal processing problems, including the analysis of hydroacoustic sonar signals to identify and speciate fish and the interpretation of acoustic signals obtained from monitoring loose parts in the primary heat transport system of CANDU systems.

Externally, the OR Department continues to be involved with universities, professional associations, and research institutes. Staff hold adjunct professorships and serve as executives or committee members with international professional societies or research granting agencies.

Chemical Research Department

The Chemical Research Department provides the Corporation with a technical resource that includes process and materials chemistry, corrosion chemistry, chemical analysis, biology, and environmental science. The areas of interest and expertise in the Department are wide and reflect the diverse chemical aspects of modern power generation. Specialized experimental facilities and state-of-the-art instrumentation for measuring and analyzing experimental parameters are used in departmental investigations. Comprehensive chemical analytical services, which support the research programs of the Division as well as the Corporation, are also offered. Work ranges from routine testing to research and development contributions that advance knowledge throughout the field. The Department is divided into six sections.

Civil Research Department

The Civil Research Department has been a leader in civil engineering technology for over seven decades. Departmental expertise, which includes key areas such as concrete technology and quality assurance, provides vital support in the construction of new facilities. Specialized geotechnical engineering support is also provided to the Division and the Corporation. Research and development projects have ranged in time and scope from the construction of Ontario Hydro's early hydraulic stations to the construction of a modern world-class power project, the Darlington Nuclear Generating Station. The Department also provides research, development, testing, and inspection services in all aspects of soil and rock sciences for both Ontario Hydro and external clients. Researchers are involved in developing and promoting the application of improved materials and practices for the civil discipline. The Department is divided into three sections.

Divisional Projects Department

The Divisional Projects Department creates and maintains connections between various groups within the Division, within the Corporation, and external to the Corporation. The Department is engaged in two major areas of work, as follows: (1) interdisciplinary research, which includes external research projects and the Director's Fund projects and (2) research management, which includes technology forecasting, business support, research management support, directorate support, and research publications.

Divisional Services Department

The Divisional Services Department is responsible for providing a variety of clerical and technical services to the engineering and scientific departments within the Research Division. Emphasis is placed on meeting the operating and business needs of the Division effectively and efficiently and on ensuring reliable functional and administrative support for Division staff. Services offered include report production; business administration; financial reporting; records, space, and safety management; printing and clerical services; model shop production; drafting; photography; payroll; and computer communication support. The Department has eight diversified sections.

Electrical Research Department

The Electrical Research Department performs research, development, and testing for the Corporation and provides technical expertise in the broad areas of power system technology, power equipment, electronics, communications, and demand management techniques. The Department strives to improve the production, transmission, distribution, and utilization of electricity. Selected areas of the natural sciences and nuclear engineering are researched, and environmental studies related to the transmission and distribution of power are conducted. The Department performs technical studies that relate to renewable energy sources and energy conservation. Researchers forecast and fulfill needs for new technology, innovation, and technical expertise to solve problems on the power system and for customers of the Corporation.
In its programs, the Department cooperates with external organizations in the solution of problems common to electric utilities. Electrical Research comprises seven sections.

Mechanical Research Department

The Mechanical Research Department provides research and development resources and experimental and specialized testing facilities in the mechanical discipline. The Department's mission is to improve the performance, reliability, and safety of materials, components, and processes used in the generation and transmission of electricity and energy. To verify safe and reliable behaviour of equipment, structures, and components, both modelling and full-scale tests are used. The Department also plays a leading role in coordinating the Research Division's contribution to developing methods of dealing with containment and immobilization of used fuel. It also concentrates on developing safe methods to store, transport, and ultimately dispose of high- and low-level nuclear wastes. Staff have earned an international reputation for extensive, leading-edge research in fall protection and the development of fall protection systems. Mechanical Research is divided into four sections.

Metallurgical Research Department

The Metallurgical Research Department provides research, development, technical services, and specialized testing facilities in the disciplines of physical metallurgy, process metallurgy, and materials science. The overall thrust of these activities is to ensure a safe and reliable supply of electrical energy and to improve the efficiency of its utilization. In pursuit of these goals, the Department deals with characteristics of materials performance and with correlation of both design intent and actual service behaviour. The majority of the Department's work program is focused toward support of CANDU technology and toward ensuring the reliability of Ontario Hydro's nuclear and coal-burning plants. At the same time, recognition is given to issues that impact on economic, environmental, and demand management. The Metallurgical Research Department is composed of five sections.

Operations Research Department

The Operations Research Department provides consulting services to all units of Ontario Hydro in the fields of operations research, mathematics, and statistics. Members of the Department organize courses, workshops, and seminars in all of these disciplines. The Department simultaneously carries out research in power system reliability. Always ready to offer applied research support when unusual and complex operational and strategic issues arise, staff use a full range of state-of-the-art mathematical and computational methodologies to arrive at workable solutions. Queries run the gamut from those related to management systems and procedures, through those concerning data and information handling, to problems related to equipment and materials. The Department is composed of one section and three units.

Awards and Achievements

Mike Bell (Electrical Research) was elected to the Advisory Board of the International Heat Pump Centre of the International Energy Agency. The Board guides the activities of the Centre, which is located at NOVEM in the Netherlands. Mike represents the International Power Utility Heat Pump Committee and provides the Centre with the electric utility perspective.

Steve Oda and Ibrahim Balbaa (Electrical Research) received the 1990 Canadian Committee on Electrotechnologies (CCE) Innovation Award. The award was presented for their development of a hybrid microwave-electric resistance kiln to process advanced ceramics. Steve was also elected to the Board of Governors of the International Microwave Power Institute (IMPI) in recognition of the Utilization Section's involvement in industrial microwave and radiofrequency heating applications.

Maier Perlman (Electrical Research) was nominated a Fellow of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). ASHRAE is one of the largest international engineering societies with over 50 000 members. Maier served for 3 years as chairman of an ASHRAE technical committee (service water heating).

The Canadian Industrial Laser Association (CILA) has instituted elections, which resulted in Jim O'Neill (Electrical Research) being acclaimed President and Len Mannik (Electrical Research) being elected to its Board of Directors.

Richard Sauvé and Jim Tulk (Mechanical Research) were awarded a New Technology Award for their contribution to the development of a Tritiated Heavy Water Transport System. Richard was involved in the analysis and design of the new transport system, and Jim conducted licensing drop tests to verify the system's structural performance under impact conditions.

Nayan Shah and Robert Zane (Mechanical Research) received a Director's Award for their development of a rocket-assisted impact system for impact testing of radioactive waste transportation containers. The system successfully simulated a collision between a locomotive travelling at 65 mph and the proposed irradiated fuel transport container (IFTC).

Jim Tulk and Dimitrios Taralis (Mechanical Research) and PK Mukherjee and Jim Sato (Civil Research) were awarded a New Technology Award for their contribution to the development of the dry storage container (DSC) for the dry storage of nuclear fuel. Savings to Hydro total over $80 million in capital costs.

In recognition of his work on conductor galloping and other forms of line vibration, Dave Havard was selected as secretary of a CIGRE (Conference on Large Electrical Systems) study committee (overhead lines), and of a working group (mechanical behaviour of conductors and fittings). CIGRE is the leading technical organization that promotes exchange of information on electrical power systems research.

Mat Cenanovic (Electrical Research) accepted an appointment as an Adjunct Associate Professor of Electrical Engineering at the University of Windsor for the period September 1, 1990 to August 31, 1993. His responsibilities will include research, development, and transfer of novel electromagnetic technologies to industry through the cooperation of Ontario Hydro, the University of Windsor, and industry.

George Anders (Electrical Research) received a New Technology Award for his contribution to the development of advanced optimizing techniques for power cable system design and operation. These techniques were embedded in a set of user-friendly cable analysis programs (CAP). CAP is a package of five software programs that analyzes steady state and transient behaviour of electric power cables.

Bert Vanderglas and Doug Scarth (Metallurgical Research) won a New Technology Award for contributing to the development of a leak-before-break technology for CANDU piping systems. The technology was applied to the design of Darlington's heat transport system. As a result, safety requirements relating to catastrophic failure of large diameter piping can be met more economically. In February 1990, the Atomic Energy Control Board (AECB) approved the design for use at Darlington NGS Unit 2.

Gary Ford and Mark Vainberg (Electrical Research) received a New Technology Award for contributing to the development of probabilistic methods and computer programs for use in transmission station design assessments. These methods make it possible to show that a higher short circuit capability exists at some older stations than was originally believed.

The 1989 Research Division W.P. Dobson Award was awarded to Chris Cheh and Ron Massey (Chemical Research) for their contribution to the development and implementation of a gas chromatographic method for separating hydrogen isotopes. The innovation attracted international recognition and earned significant financial rewards for the Corporation.

Mark Tinkler, Scott McNabb, Ken Yiu, and Murray Mathers (Metallurgical Research) and Gil Poon (formerly of Metallurgical Research, now Production Branch) won the 1989 H.A. Smith Award for their development and field demonstration of a portable robotic system for in situ repair of cavitation damage to hydraulic turbine runners.

Al Donner (Metallurgical Research) was awarded a 1989 Director's Award for his contribution to the development of innovative experimental facilities relating to loss of coolant accident (LOCA) simulations. Al's role was to develop experimental techniques and to construct apparatus.

Krish Radhakrishna, KC Lau, Bob Dowdell, and Bob Watts (Civil Research) were winners of a 1989 Director's Award for their contribution to nuclear waste disposal research. The work attracted international acclaim and successfully resolved crucial questions relating to the design of waste disposal vaults.

Ray Marttila (Electrical Research) won a 1989 Director's Award for his contribution to the development of power system protection systems. Ray was instrumental in developing novel techniques for the analysis of impedance-based protection systems; the theory for the first system to completely protect the stator winding on thermal units; and the theory and subsequent implementation of a universal directional relay aid in the protection of heavily loaded lines.

Craig Simpson (Divisional Projects) won the Presidential Award of the Canadian University-Industry Council of Advanced Ceramics (CUICAC). The award was for his contribution to the growth and well-being of the organization. Craig also served as chairman of CUICAC's Business and Finance Committee.

Miriam Mozes and Rene Mangal (Chemical Research) were awarded a 1989 New Business Ventures Excellence Award for contributing to Ontario Hydro's international business. The SONOX process, which can be used for controlling SO_2 and NO_x emissions in power plant flue gases, was invented by Miriam Mozes, Rene Mangal, and Raja Thampi.

John Kuffel (Electrical Research) was awarded a 1989 New Business Ventures Award for his proposal to design, procure, and commission a high-voltage test laboratory for the Jordanian Electricity Authority. Unfortunately, the proposal was deferred due to federal budget cuts. Nevertheless, NBV recognized John's efforts and those of team members Ernie Jones and Jack Edgar.

The publications produced in the Research Publications Office continue to attract the attention of the Society for Technical Communication (STC). Last year, the *Services and Capabilities* brochure won the Distinguished Award, the *Research Annual* and *Chit Chat* awards of excellence for writing and design, and the series of bookmarks, *Hydrolines*, was recognized by an Award of Achievement. Drafting's input into the *Research Annual*, in the form of technical art, also received an Achievement award. The STC is the largest professional organization devoted to the arts and sciences of technical communication.

Resources and Costs

Occupational Classification of Staff

- Management & Professional (324)
- Technicians & Technologists (253)
- Support Staff (71)

Total costs including those for space, materials, equipment, and work done ($M)

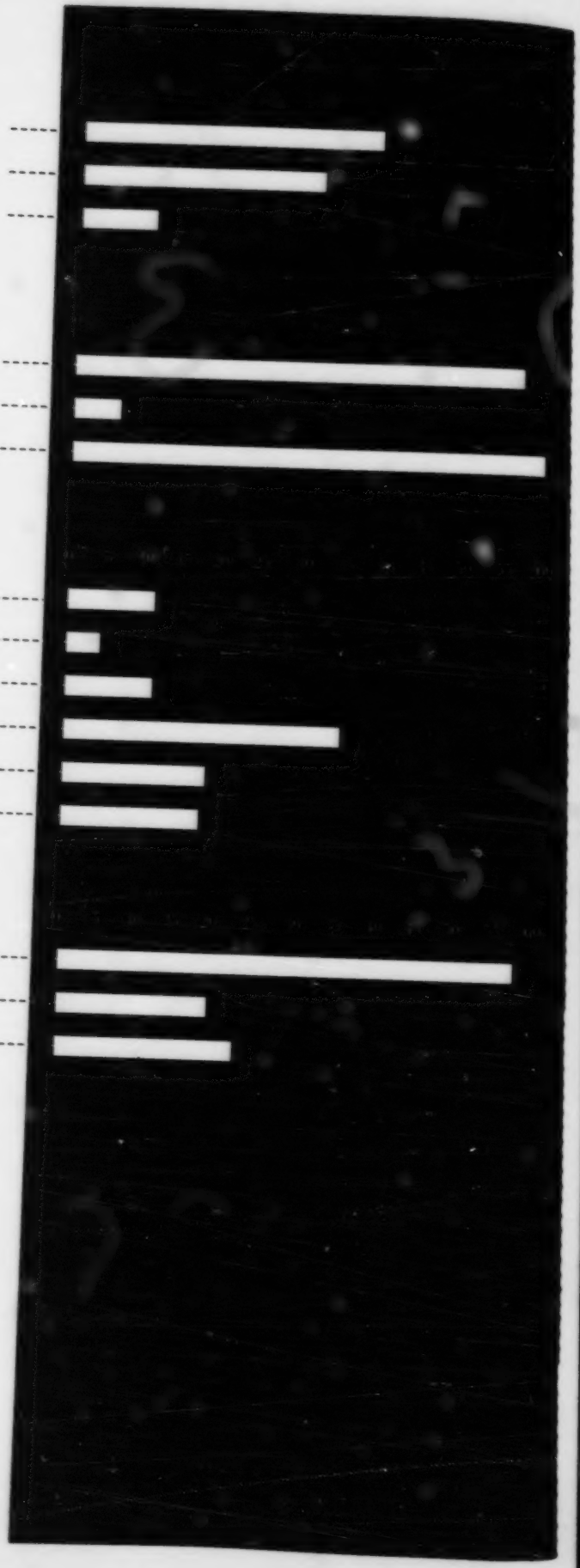
- Research Division OM&A (37.7)
- Revenue from work for other organizations (4.2)
- Transfers to other Ontario Hydro Branches (39.2)

Proportions of Research Division Costs for Various Categories of Work (% of Total Costs)

- Testing (12)
- Consultation (4)
- Technical Investigation (12)
- Research & Development, Current Needs (35)
- Research & Development, Future Needs (19)
- General (18)

Research Cost Breakdown by Major Resource Categories (% of Gross Costs)

- Salary and Benefits (57)
- Indirect Costs (20)
- Direct Costs to Projects (23)



Research Division's Major Programs:
Proportions by Actual Gross (%) Costs for 1990

Utilization (8)
Provides research and development (R&D), technological innovation, and technical support to improve power utilization.

Electric Power Systems (6)
Enhances operating efficiency and reliability of the bulk power system in the areas of generator and system controls, system protection, machine diagnostics, instrumentation, and reliability assesment.

Transmission (12)
Provides technological support and innovation directed toward improving the reliability of existing stations and lines.

Distribution Systems (4)
Provides innovations to improve Ontario's distribution and retail delivery systems.

Nuclear Generation (33)
Provides R&D in support of the continued efficient, reliable, and safe operation of Ontario Hydro's nuclear generating units.

Nuclear Waste (4)
Provides R&D to ensure the safe, long-term management of Ontario Hydro's nuclear wastes.

Thermal Generation (5)
Provides R&D to assist the fossil-fuelled generating stations maintain and extend their reliable and efficient operation and helps them meet environmental regulations.

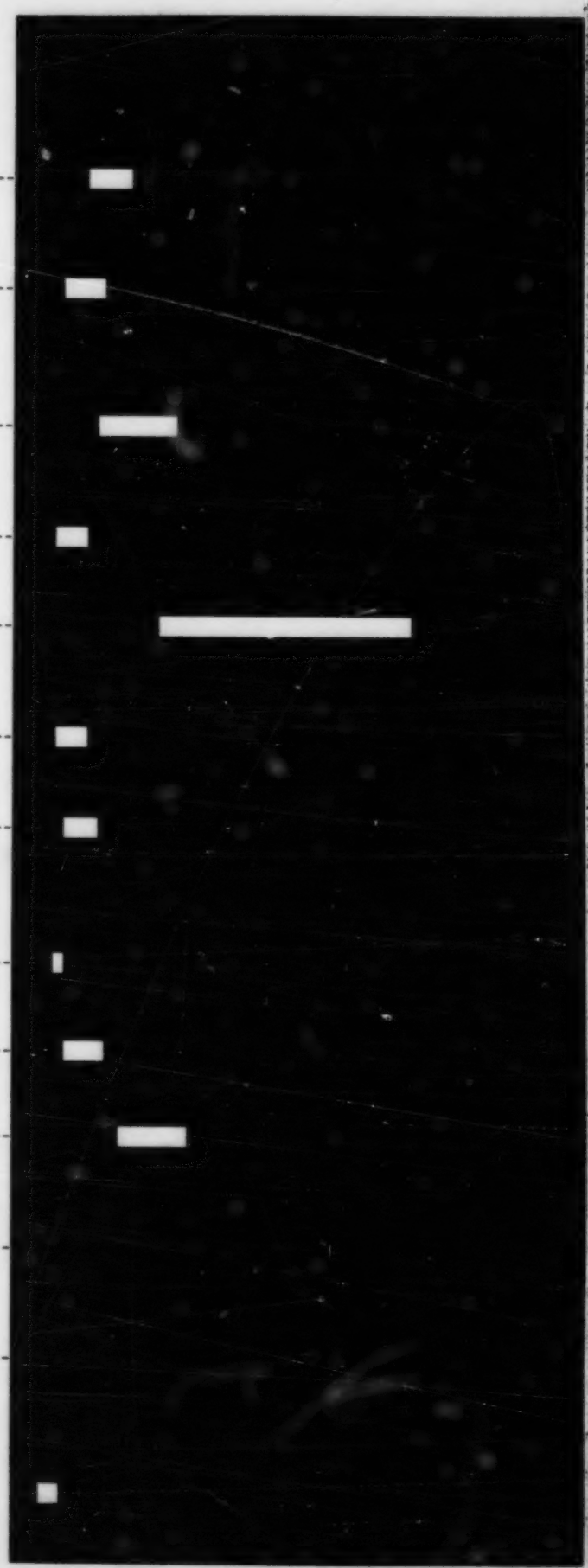
Hydraulic Generation (2)
Provides R&D to ensure the continued efficient operation of hydraulic generating stations.

Environmental Impact (6)
Provides a scientific understanding of the effects of Ontario Hydro's operations on the natural environment.

General Research (13)
Provides general technical services to the Corporation in operations research, materials and equipment testing, and chemical analysis.

External Research Support (3)
Provides the Corporation with timely access to leading edge technology by involvement in collaborative R&D and support of external research organizations.

Human Resource Development (4)
Maintains and develops the capability of the Research Division staff to perform work at a high performance level.



Glossary

AECB	Atomic Energy Control Board
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BLIP	Blister Location Inspection Package
CANDU	Canadian Deuterium Uranium (reactors)
CANMET	Canada Centre for Mineral and Energy Technology
CAP	Cable Analysis Programs
CbF	Capability Factor
CCE	Canadian Committee on Electrotechnologies
CEA	Canadian Electrical Association
CFFTP	Canadian Fusion Fuels Technology Program
CIGAR	Channel Inspection and Gauging Apparatus for Reactors
CIGRE	Conference on Large Electrical Systems
CILA	Canadian Industrial Laser Association
CNC	Computerized Numerical Control
CUICAC	Canadian University-Industry Council of Advanced Ceramics
DPD	Divisional Projects Department
DSC	Dry Storage Container
EA	Environmental Assessment
EMB	Energy Management Branch
EMFRAP	Electric and Magnetic Fields Risk Assessment Program
EPRI	Electric Power Research Institute
ETDF	Electrochemical Testing and Development Facility
GEMS	Generator Expert Monitoring System
GIS	Gas-Insulated Switchgear
ICE	Integrated Computing Environment
IEEE	Institute of Electrical and Electronics Engineers
IFTC	Irradiated Fuel Transport Container
IGCC	Integrated Gasification Combined Cycle
IMPI	International Microwave Power Institute
LOCA	Loss of Coolant Accident
LSDA	Limestone Dual Alkali
MISA	Municipal and Industrial Strategy for Abatement
NDE	Nondestructive Evaluation
NSERC	Natural Sciences and Engineering Research Council
OM&A	Operation, Maintenance, and Administration
OPGW	Fibre-optic Cored Overhead Ground Wires
OR	Operations Research
PALC/AIM	Programmable Auxiliary Logic Controller/Analog Input Module
PIPE	Packaged Inspection Probe (system)
R&D	Research and Development
SLAR	Spacer Location and Repositioning
STC	Society for Technical Communication
SWORD	Severe Weather Forecast and Detection System
TLRP	Transmission Line Refurbishment Program
VOCs	Volatile Organic Compounds
WHMIS	Workplace Hazardous Materials Information System
XIPD	X-ray Induced Partial Discharge (system)

Publications

Ahluwalia AK, Chan AM.
Three-dimensional simulation of jet flow impacting onto a plate inside an enclosure. *Proc of the 3rd Intl Conf on Simulation Methods in Nuclear Engineering*, Montreal, PQ, April 18-20, 1990.

Amm DE, Havard DG, Horrocks DE, Horrocks DJ, Macedo FX.
Development of a high voltage transmission line refurbishment program at Ontario Hydro. *Proc of CIGRE*, Paper No 22-201, Paris, France, August 26-September 1, 1990.

Anandakumaran K, Stonkus DJ.
Determination of PVC cable insulation degradation. *Proc of the Soc of Plastics Engineers Conf, ANTEC 90*, Dallas, TX, May 7-11, 1990.

Anders GJ, Endrenyi J, Ford GL, Stone GC.
A probabilistic model for evaluating the remaining life of electrical insulation in rotating machines. *Trans on Energy Conversion of the IEEE Power Engineering Soc Winter Meeting*, Atlanta, GA, February 4-7, 1990.

Anders GJ, Endrenyi J, Pereira MV*, Pinto LM*, Oliveira CG*, Cunha SH*.
Fast Monte Carlo simulation techniques for power system reliability studies. *Proc of CIGRE*, Paris, France, August 26-September 1, 1990.

Anders GJ, Ford GL, Vainberg M, Arnot SJ, Germani MD.
Grounding hazard risk assessment methods. *Proc of the 4th Intl Conf on Short Circuits in Power Systems*, Liege, Belgium, September 3-5, 1990.

Anders GJ, Roiz JA*, Moshref A*.
Advanced computer programs for power cable ampacity calculations. *IEEE Computer Applications in Power* 3(3):42-45, July 1990.

Anderson HL: see **Hanson WG** et al, **Ramani N** et al

Arnot SJ: see **Anders GJ** et al

Arron GP.
Translocation of uniconazole after trunk injection of silver maple saplings. *J Plant Growth Regulation* 9: 141-146, 1990.

Balbaa IS: see **Oda SJ** et al

Barber BT: see **Oda SJ** et al

Barton RA: see **Durham MD*** et al

Bechai M: see **Dayal R** et al

Boyer AE: see **Farzaneh M*** et al

Braun JM, Brown G.
Operational performance of generator condition monitors: comparison of heated and unheated ion chambers. *Proc of the IEEE Power Engineering Soc Winter Meeting*, Atlanta, GA, February 4-9, 1990.

Braun JM, Fujimoto N, Stone GC, Boggs SA*, Addis G*, Diederich KJ*, Diessner A*, Luxa G*, Girodet A*.
Long-term reliability of cast epoxy insulators in gas-insulated equipment. *Proc of CIGRE*, Paris, France, August 26-September 1, 1990.

Braun JM, Rizzetto S, Fujimoto N, Diederich KJ*, Girodet A*.
Behavior of GIS epoxy insulators with metallic inclusions. *Proc of the IEEE Conf on Electrical Insulation and Dielectric Phenomena*, Pocono Manor, PA, October 28-31, 1990.

Braun JM: see **Fujimoto N** et al, **Stone GC** et al

Brennenstuhl AM: see **McIntyre NS*** et al

Brown D.
Comparison of two methods of estimating the seed bank of a recently cleared right-of-way. *Bull of the Ecological Soc of Am* 71(2):104, June 1990.

Brown G: see **Braun JM**

Brown RM*, Ogram GL, Spencer FS.
Oxidation and dispersion of HT in the environment: the August 1986 field experiment at Chalk River. *Health Phys* 58(2):171-181, February 1990.

Brown SK: see **Mannl L**

Camacho F, Vascotto GL.
Changes in precipitation patterns evident from Canadian climate records. *Proc of the Intl & Transboundary Water Resources Issues, A Joint Meeting of the Am & Can Water Resources Assoc*, Toronto, ON, April 1-4, 1990.

Chan AM, Abdul-Razzak A*, Shoukri M*.
Two-phase flow regimes during the rewetting and refilling of hot horizontal tubes. *Experimental Thermal and Fluid Science* 3(5):330-337, May 1990.

Chan AM, Bzovey D*.
Measurement of mass of flux in high temperature high pressure steam-water two-phase flow using a combination of pitot tubes and a gamma densitometer. *Nuclear Engineering and Design* 122: 95-104, 1990.

Chan AM, Shoukri M*, Dundas M*.
Minimizing temperature measurement errors in solids using a thermocouple-plug assembly. *Proc of the 9th Intl Heat Transfer Conf*, Jerusalem, Israel, August 19-24, 1990.

Chan AM: see **Ahluwalia AK, Dowlati R*** et al

Chan HT: see **Wang Zhao Jing***

Cheung RW: see **Dick EP** et al

Chu FY: see **Mayer P** et al, **Vieira CS***

Cilic RM: see **Mayer P** et al

Clark MA: see **Westwood HJ** et al

*Denotes other than Ontario Hydro employee.

Claudi R, Evans DW.
Chemical addition strategies for zebra mussel control in once-through cooling systems. *Proc of the EPRI Intl Macrofouling Symp*, Orlando, FL, December 4-6, 1990.

Cress SL, Motlis J.
Temperature rise of submarine cables on riser poles. *Trans on Power Delivery of the IEEE Summer Power Meeting*, Minneapolis, MN, July 17, 1990.

Culbert IM: see **Stone GC** et al

Cuthbert DF: see **Young DJ** et al

Dandeno PL*, Service JR.
Experience with translation of turbogenerator operational test data, and corresponding D & Q axis stability models, into standard inductance and time constant forms. *Proc of the 10th Power Systems Computation Conf*, Graz, Austria, August 19-24, 1990.

Dawson CW: see **Durham MD*** et al

Dayal R, Zhou Z*.
Characterization and leaching studies of FGD waste by-products. *Waste Management* 10:53, 1990.

Dayal R, Zhou Z*, Bechai M, Klein R.
Bedrock gypsum dissolution studies at Ontario Hydro's R.H. Saunders GS. *Proc of the 43rd Can Geotechnical Conf*, Québec City, PQ, October 10-12, 1990.

Desai YM*, Popplewell N*, Havard DG, Shah AH*.
Static and dynamic behavior of mechanical components associated with electrical transmission lines - III(B). *Shock & Vibration Digest* 22(3):3-10, March 1990.

Dhirani H: see **Stone GC** et al

Di Biasio E: see **Mayer P** et al

Dias SA, Nott BR.
Selective sorbents for water purification in nuclear systems. *Proc of the 51st Intl Water Conf*, Pittsburgh, PA, October 21-24, 1990.

Dick EP, Cheung RW, Porter JW.
Generator models for overvoltage simulations. *Trans on Power Delivery of the IEEE Power Engineering Soc Winter Meeting*, Atlanta, GA, February 4-9, 1990.

Dick EP, Gupta BK, Porter JW*, Greenwood A*.
Practical design of generator surge protection. *Trans on Power Delivery of the IEEE Power Engineering Soc Winter Meeting*, Atlanta, GA, February 4-7, 1990.

Dowlati R*, Kawaji M*, Chan AM.
Pitch-to-diameter effect on two-phase flow across an in-line tube bundle. *AIChE J* 36(5):765-772, May 1990.

Dunstall TG, Carter JCH*, Monroe BP*, Haymes GT, Weller RR*, Hopkins GJ*.
Influence of upwellings, storms and generating station operation on water chemistry and plankton in the Nanticoke region of Long Point Bay, Lake Erie. *Can J Fish Aquat Sci* 47(7):1434-1445, 1990.

Dunstall TG, Lawler DW, Farooqui R, Haymes GT.
Variation in lake water temperature in the Long Point Bay region of Lake Erie during the open-water season. *Can J Fish Aquat Sci* 47(7):1427-1433, 1990.

Durham MD*, Holstein D*, Rhudy RG*, Altman RF*, Burnett TA*, DeGuzman J*, Hollinden GA*, Barton RA, Dawson CW.
Effects of coal chloride and spray dryer operating variables on particle cohesion and resistivity in downstream ESPs. *Proc of the EPRI/EPA SO_3 Control Symp*, New Orleans, LA, May 8-11, 1990.

Durham MD*, Rhudy RG*, Burnett TA*, DeGuzman J*, Hollinden GA*, Barton RA, Dawson CW.
Identification of low-resistivity reentrainment in ESP's operating in dry scrubbing applications. *Proc of the 8th Symp on the Transfer & Utilization of Particulate Control Technology*, San Diego, CA, March 20-24, 1990.

Dyck RW, Marchand A*, Spekkens P, Verma K*.
Operational experience with steam generators in Canadian nuclear power plants. *Proc of the CNS/ANS Conf on Steam Generators & Heat Exchangers*, Toronto, ON, April 30-May 2, 1990.

Endrenyi J: see **Anders GJ** et al, **Salvaderi L*** et al

Evans DW, Nott BR.
Treatment and disposal of steam generator and heat exchanger chemical cleaning wastes. *Proc of the Waste Management Conf*, Tucson, AZ, February 25-March 1, 1990.

Evans DW: see **Claudi R**

Farooqui R: see **Dunstall TG** et al

Farzaneh M*, Druez J*, Melo OT, Boyer AE.
Current studies in insulator wetting and icing by fog accretion. *Proc of the CEA E&O Division Spring Meeting*, Montreal, PQ, March 26, 1990.

Fleck RG: see **Perovic V** et al

Ford GL: see **Anders GJ** et al

Frost CR: see **Konecny L** et al

Fujimoto N, Rizzetto S, Braun JM, Stone GC.
Characteristics of ultra low level partial discharges in GIS epoxy insulators. *Proc of the 6th Intl Symp on Gaseous Dielectrics*, Knoxville, TN, September 23-27, 1990.

Fujimoto N: see **Braun JM** et al

Gaikwad RP: see **Mozes MS** et al

Germani MD: see **Anders GJ** et al

Gierszewski PJ, Davidson CM*, Drexler DJ*, Headon AC, Kirk DW*.
Preliminary measurements of materials compatibility with LiOH and $LiNO_3$ aqueous salt solutions at under 100°C. *Fusion Engineering and Design* 13:53-57, 1990.

Gonzalez F, King PJ.
Corrosion performance of alloy 800 tubing under CANDU steam generator conditions. *Proc of the Intl Symp, FONTEVRAUD II, Royal Abbey of Fontevraud,* Chinon, France, September 10-14, 1990.

Gonzalez F, Pagan SM.
Hideout return studies in CANDU steam generators. *Proc of the CNS/ANS Conf on Steam Generators & Heat Exchangers,* Toronto, ON, April 30-May 2, 1990.

Griffin JD.
Impact of power electronics on a large power system - power quality degradation and related effects. *Proc of the IERE Workshop on Applications of Power Electronics to Power Facilities,* Tokyo, Japan, September 11-14, 1990.

Gupta BK, Lloyd BA, Sharma DK.
Degradation of turn insulation in motor coils under repetitive surges. *Trans on Energy Conversion of the IEEE Power Engineering Soc Winter Meeting,* Atlanta, GA, February 4-8, 1990.

Gupta BK, Nilsson NE*, Sharma DK*.
Protection of motors against high voltage switching surges. *Trans of the IEEE PES - Intl Power Meeting,* New Delhi, India, October 28-November 1, 1990.

Gupta BK, Stone GC.
Partial discharge monitoring in instrument transformers. *Proc of the EPRI Workshop on Failed High Voltage Instrument Transformers,* Palo Alto, CA, August 23-27, 1990.

Gupta BK: see **Dick EP** et al, **Stone GC** et al

Hanson WG, Anderson HL, Ramani N, Zbroja S, Patrick PH.
Neural network monitoring in CANDU nuclear power stations. *Proc of the Neural Networks Conf,* London, England, November 19-21, 1990.

Hanson WG: see **Ramani N** et al

Havard DG, Pon CJ.
Use of detuning pendulums for control of galloping of single conductor and two- and four-conductor bundle transmission lines. *Trans of the 5th Intl Workshop on Atmospheric Icing of Structures,* Tokyo, Japan, October 29-November 1, 1990.

Havard DG: see **Amm DE** et al, **Desai YM*** et al

Haymes GT: see **Dunstall TG** et al

Headon AC: see **Gierszewski PJ** et al

Holzhueter IB: see **Schumacher LC** et al

Hooton RD, Konecny L.
Permeability of grouted fractures in granite. *Concrete Intl* 12(7):48-56, July 1990.

Horrocks DE: see **Amm DE** et al

Horrocks DJ: see **Amm DE** et al

Husain A.
A simple relationship between radiographic film density and film exposure. *Materials Evaluation* (11):1285, October 1990.

Husain A: see **Krasznai JP**

Jhajj IS: see **Jones WR** et al

Jones WR, Jhajj IS, Gough BD*.
Improved modelling of residential thermal envelope for energy conservation upgrade assessment. *Proc of the ACEEE Summer Study on Energy Efficiency in Buildings,* Pacific Grove, CA, August 26-September 1, 1990.

Jones WR, Wong MT*, Jaisareesingh J*.
Residential thermal comfort and ventilation effectiveness in a full-scale test room. *Proc of the 5th Intl Conf on Indoor Air Quality and Climate,* Toronto, ON, July 29-August 3, 1990.

King PJ: see **Gonzalez F**

Kjartanson BH*, Radhakrishna HS, Lau KC.
Geotechnical instrumentation for in situ assessment of bentonite-sand buffer. *Proc of the 1st Biannual Environmental Specialty Conf, Can Soc for Civil Engineers,* Hamilton, ON, May 16-18, 1990.

Klein R: see **Dayal R** et al

Konecny L, Mukherjee PK, Frost CR.
Leaching of concrete. *Proc of the Advances in Cementitious Materials Conf, Am Ceramic Soc Inc,* Gaithersburg, MD, July 23-26, 1990.

Konecny L: see **Hooton RD, Mukherjee PK**

Kramer SM: see **O'Brien MS*** et al

Krasznai JP, Husain A.
Radioactive incinerator ash — a mixed waste. *Proc of the 2nd Intl Seminar on Radioactive Waste Products,* Julich, Germany, May 28-June 1, 1990.

Kuffel J, Malewski R*, Van Heeswijk RG*.
Modelling of the dynamic performance of transient recorders used for high voltage impulse tests. *Trans on Power Delivery of the IEEE Summer Power Meeting,* Minneapolis, MN, July 17, 1990.

Lau KC: see **Kjartanson BH*** et al

Lawler DW: see **Dunstall TG** et al

Lawson WHS.
Welding in electric utilities. *Can Welder & Fabricator* 81(7-8):79-83, July-August 1990.

Lee WK: see **Scarth DA**

Lenarduzzi FJ.
A direct expansion ground source heat pump with spiral ground coil. *Proc of the 3rd Intl Workshop on Research Activities on Advanced Heat Pumps,* Graz, Austria, September 24-26, 1990.

Lloyd BA: see **Gupta BK** et al, **Stone GC** et al

Lyles JF: see **Stone GC** et al

Macedo FX: see **Amm DE** et al

Mangal R: see **Mozes MS** et al

Mannik L, Brown SK.
A relationship between laser power, penetration depth and welding speed in the laser welding of steels. *J Laser Applications* 2(3 & 4):22-25, Summer/Fall 1990.

Manolescu AV: see **Mayer P**

Mayer P.
Boiler tube failure mechanism recognition — an expert system. *Can Institute of Mining and Metallurgy Bull* 83(939):92-95, July 1990.

Mayer P, Di Biasio E, Cilic RM, Chu FY.
Materials characterization techniques for high temperature superconductors. *Ceramica Acta* 2(50): 1-15, July 1990.

Mayer P, Manolescu AV.
Oxidation of boiler tubes in steam. *Proc of the Intl Symp on High Temperature Oxidation and Sulphidation Processes*, August 26-30, 1990.

McIntyre NS*, Weisener CG*, Davidson RD*, Lennard WN*, Massoumi GR*, Mitchell IV*, Brennenstuhl AM, Warr BD.
Analysis of zirconium-niobium pressure tube surfaces for hydrogen using secondary ion mass spectrometry (SIMS). *Surface and Interface Analysis* 15, 1990.

Melo OT: see **Farzaneh M*** et al

Morandin GD: see **Sauvé RG** et al

Motlis J: see **Cress SL**

Mozes MS, Gaikwad RP, Mangal R.
Activation and recycling of waste from in-furnace slurry injection process for SO_2 control. *Proc of the EPRI/EPA SO_2 Control Symp*, New Orleans, LA, May 8-11, 1990.

Mukherjee PK.
Monitoring concrete quality of a nuclear containment structure. *Proc of the RILEM Workshop on Testing During Concrete Construction*, Darmstadt, Germany, March 5, 1990.

Mukherjee PK.
Quality control and specifications of supplementary cementing materials through standardization. *Proc of the 13th Workshop on Advanced Cements, Canadian University-Industry Council on Advanced Ceramics*, Toronto, ON, June 4-5, 1990.

Mukherjee PK: see **Konecny L**

Nadeau E: see **Sauvé RG** et al, **Scarth DA** et al

Narang A.
Detailed transformer model for EMTP, part II: magnetic model. *EMTP Review* 4(2), April 1990.

Nott BR: see **Dias SA, Evans DW**

O'Brien MS*, Sinclair AN*, Kramer SM.
High resolution deconvolution using lease-absolute-values minimization. *Proc of the IEEE Ultrasonics Symp*, Honolulu, HI, December 3-7, 1990.

Oda SJ.
Utility-sponsored industrial microwave application: accelerated slipcasting and drying of ceramics. *Proc of the Intl Microwave Power Symp*, Denver, CO, August 25-27, 1990.

Oda SJ, Balbaa IS, Barber BT.
The development of new microwave heating applications at Ontario Hydro's Research Division. *Proc of the Materials Research Soc Spring Meeting Microwave Symp*, San Francisco, CA, April 16-21, 1990.

Oda SJ, Balbaa IS, Woods BG, Barber BT.
Drying of clay and ceramic bodies. *Proc of the CCE Conf*, Calgary, AB, April 2-3, 1990.

Ogram GL: see **Brown RM*** et al

Pagan SM: see **Gonzalez F**

Patrick PH: see **Hanson WG** et al, **Ramani N** et al

Perovic V, Weatherly GC*, Fleck RG.
C-component dislocations in sub-boundaries in a Zr-2.5 wt% Nb alloy. *J Nuclear Materials* 171:327-338, 1990.

Pon CJ: see **Havard DG**

Porter JW: see **Dick EP** et al

Radhakrishna HS: see **Kjartanson BH*** et al

Ramani N, Patrick PH, Hanson WG, Anderson HL.
Fish detection and classification using a neural network based active sonar system — preliminary results. *Proc of the Intl Joint Conf on Neural Networks*, Washington, DC, January 15-19, 1990.

Ramani N: see **Hanson WG** et al

Rizzetto S: see **Braun JM** et al, **Fujimoto N** et al

Rodgers DW, Schroder JU, Craig GR*, Jonczyk E*.
Comparing toxicity — QA/QC aspects of Ontario Hydro's MISA bioassays. *Proc of the 17th Annual Aquatic Toxicity Workshop*, Vancouver, BC, November 5-7, 1990.

Salvaderi L*, Allen R*, Billinton R*, Endrenyi J, McGillis D*, Lauby M*, Manning P*, Ringlee R*.
State of the art of composite-system reliability evaluation. *Proc of CIGRE*, Paris, France, August 26-September 1, 1990.

Sato JA: see **Vecchio FJ***

Sauvé RG.
Theory and application of CDEPTH. *Proc of the Seminar on Creep/Growth Technology, AECL CANDU-Operations*, Oakville, ON, June 22, 1990.

Sauvé RG, Morandin GD, Nadeau E.
Impact simulation of liquid-filled containers including fluid-structure interaction. Part I - theory, part II - experimental verification. *Proc of the ASME Pressure Vessel & Piping Conf*, Nashville, TN, June 17-21, 1990.

Sauvé RG: see **Scarth DA** et al

Scarth DA, Lee WK.
The fatigue behaviour of hydrided Zr-2.5 wt% Nb pressure tube material. *Proc of the 4th Intl Conf on Fatigue and Fatigue Thresholds, Fatigue 90*, Honolulu, HI, July 15-20, 1990.

Scarth DA, Sauvé RG, Nadeau E.
Assessment of the structural integrity of CANDU Zr-Nb pressure tubes for the fuel channel spacer repositioning operation. *Proc of the ASME Pressure Vessel and Piping Conf*, Nashville, TN, June 17-21, 1990.

Schroder JU: see **Rodgers DW** et al

Schumacher LC, Holzhueter IB, Hill IR*, Dignam MJ*.
Semiconducting and electrocatalytic properties of sputtered cobalt oxide films. *Electrochimica Acta* 35(6):975-984, 1990.

Schumacher LC, McIntyre NS*, Mamiche-Afara S*, Dignam MJ*.
Photoelectrochemical properties of indium doped iron oxide. *J Electroanal Chem* 277:121-138, 1990.

Sedding HG: see **Stone GC** et al

Service JR: see **Dandeno PL***

Sharma DK: see **Gupta BK** et al

Sidey D: see **Westwood HJ** et al

Sim SH, Templeton JG*.
Further results for the M/M(a,∞)/N batch-service system. *Queueing Systems* 6:277-286, 1990.

Spekkens P: see **Dyck RW** et al

Spencer FS: see **Brown RM*** et al

Stone GC, Culbert IM, Dhirani H.
Flowchart procedure to assess the condition of turbine generator insulation. *Proc of the IEEE Power Engineering Soc Winter Meeting*, Atlanta, GA, February 4-9, 1990.

Stone GC, Gupta BK, Lyles JF, Sedding HG.
Experience with accelerated aging tests on stator bars and coils. *Proc of the IEEE Intl Symp on Electrical Insulation*, Toronto, ON, June 3-6, 1990.

Stone GC, Sedding HG, Bernstein BS*.
Improved thermal monitoring of rotating machine insulation. *Proc of the EPRI Workshop*, Baltimore, MD, April 10-11, 1990.

Stone GC, Sedding HG, Lloyd BA, Braun JM, Bernstein BS*, White JC*.
Improved rotating machine insulation condition assessment. *Proc of CIGRE*, Paris, France, August 26-September 1, 1990.

Stone GC, vanHeeswijk RG*.
Surge-induced electroluminescence in epoxy. *Proc of the Nordic Insulation Conf*, Copenhagen, Denmark, June 18-20, 1990.

Stone GC: see **Anders GJ** et al, **Braun JM** et al, **Fujimoto N** et al, **Gupta BK**

Stonkus DJ: see **Anandakumaran K**

Strack JT.
An overview of drying and concentrating applications. *Proc of the Electrotechnologies National Conf*, Calgary, AB, April 2-3, 1990.

Sulowski AC, Brinkley JW*.
Measurement of maximum arrest force in performance tests of fall protection equipment. *J Testing & Evaluation* 18(2):123-127, March 1990.

Thomas GF.
Excitation of a multilevel system by a train of identical phase-coherent Gaussian-shaped laser pulses. *Phys Rev A* 41(3):1645-1652, February 1990.

Thomas GF.
Propensity for iron (II) oxalate precipitation in CAN-DECON decontaminations of CANDU primary heat transport systems. *Ann Nuclear Energy* 17(10):531-544, October 1990.

Vainberg M: see **Anders GJ** et al

Vascotto GL: see **Camacho F**

Vecchio FJ*, Sato JA.
Thermal gradient effects in reinforced concrete frame structures. *Am Concrete Inst Structural J* 87(3):262-275, May-June 1990.

Vieira CS*, Chu FY.
Recent developments in S_2F_{10} research. *Proc of the Intl Electrical Research Exchange Workshop on Gas-Insulated Substations*, Toronto, ON, September 30-October 4, 1990.

Wang Zhao Jing*, Chan HT.
The application of fly ash in geotechnical engineering projects. *Chinese Geotechnical Engineering J* 12(3):98-107, May 1990.

Warr BD: see **McIntyre NS*** et al

Westwood HJ, Clark MA, Sidey D.
Creep failure and damage in main steam line weldments. *Proc of the 4th Intl Conf on Creep & Fracture of Engineering Materials & Structures*, Swansea, UK, April 1-6, 1990.

Woods BG: see **Oda SJ** et al

Yap S.
CEA cold climate heat pump controller. *Proc of the Heat Pumps in Cold Climates Conf*, Moncton, NB, August 13-14, 1990.

Yap S: see **Young DJ** et al

Young DJ, Cuthbert DF, Yap S.
Operating experience with different kinds of air-source heat pumps in Canadian winters. *Proc of the 3rd Intl Energy Agency Heat Pump Conf*, Tokyo, Japan, March 12-15, 1990

Zbroja S: see **Hanson WG** et al

Presentations

Allen AL: see **Groeger JH*** et al

Anandakumaran K, Stonkus DJ.
Assessing insulation degradation by physical and chemical techniques. *Institute of Electrical and Electronics Engineers Conf*, Toronto Chapter, Toronto, ON, September 26, 1990.

Anandakumaran K, Stonkus DJ.
Polymer degradation due to thermal and radiation damage. *Union Carbide*, Connecticut, November 29, 1990.

Anders GJ.
Advanced cable ampacity program. *CEA E&O Division Spring Meeting*, Montreal, PQ, March 28, 1990.

Anders GJ.
Transient thermal analysis of power cables. *CEA E&O Division Spring* Meeting, Montreal, PQ, March 26, 1990.

Anderson HL, Hanson WG, Patrick PH, Ramani N, Zbroja S.
Loose parts monitoring in Ontario Hydro's CANDU power stations. *CNS/ANS Conf on Steam Generators & Heat Exchangers*, Toronto, ON, April 30-May 2, 1990.

Anyas-Weiss N, Mills D, Vascotto GL.
Management intervention and long-range research. *2nd Intl Conf on Management of Technology*, Miami, FL, February 28-March 2, 1990.

Anyas-Weiss N, Simpson CJ, Mills D.
University-industry research collaboration. *Can Conf on Engineering Education*, Toronto, ON, June 27-28, 1990.

Armstrong PJ: see **Sumar RN** et al

Arron GP, Bremner LA.
Metabolism of uniconazole (XE-1019) in wood and foliage of silver maple saplings after trunk injection. *Intl Soc of Arboriculture Annual Meeting*, Toronto, ON, August 12-15, 1990.

Arron GP: see **Sherar MD*** et al

Barreca SL: see **Hartlen RT** et al

Barton RA, Dawson CW, Burnett TA*, Hollinden GA*, Wertz KL*, Blythe GM*, Rhudy RG*.
SO_2 removal performance improvements by chloride addition at the TVA 10-MW spray dryer/ESP pilot plant. *EPRI/EPA SO_2 Control Symp*, New Orleans, LA, May 8-11, 1990.

Bartoszek FE: see **Morrison HD** et al

Bellamy G: see **Brennenstuhl AM** et al

Bérubé GR, Giesbrecht WJ*, Pearson WR*.
A digital power system stabilizer. *CEA Transmission System Planning and Operations Section Spring Meeting*, Montreal, PQ, March 26-29, 1990.

Braun JM.
Long term dielectric aging mechanisms in GIS. *IERE Workshop*, Toronto, ON, October 1-3, 1990.

Braun JM, Chu FY, Seethapathy R*.
A surface resistivity probe for assessing solid insulators in GIS. *IEEE Intl Symp on Electrical Insulation*, Toronto, ON, June 4-6, 1990.

Braun JM: see **Groeger JH*** et al

Bremner LA: see **Arron GP, Sherar MD*** et al

Brennenstuhl AM, Doherty PE.
The economic impact of microbiologically influenced corrosion at Ontario Hydro's nuclear power plants. *Intl Congress on Microbially Influenced Corrosion*, Knoxville, TN, October 7-12, 1990.

Brennenstuhl AM, Doherty PE, King PJ, Dunstall TG.
The effects of biofouling on the corrosion of nickel heat exchanger alloys at Ontario Hydro. *Intl Congress on Microbially Influenced Corrosion*, Knoxville, TN, October 7-12, 1990.

Brennenstuhl AM, Doherty PE, Dunstall TG, Bellamy G, King PJ.
The corrosion of freshwater cooled nickel alloy heat exchangers at Ontario Hydro. *Steam Generator & Heat Exchanger Conf*, Toronto, ON, April 30-May 2, 1990.

Brennenstuhl AM: see **McIntyre NS*** et al, **Warr BD** et al

Brown J.
Materials problems in the Canadian electric power industry. *Annual Retreat of the Ontario Centre for Materials Research*, Alliston, ON, September 28, 1990.

Brown J, Spekkens P, Lister DH*, Miglin B*.
An overview on R&D in support of CANDU steam generators. *CNS/ANS Conf on Steam Generators & Heat Exchangers*, Toronto, ON, April 30-May 2, 1990.

Buchan PG.
Protecting radio equipment against lightning damage. *Mississauga Radio Amateur Club*, Mississauga, ON, March 8, 1990.

Bunnenberg C*, Taeschner M*, Ogram GL.
Key processes and parameters for environmental tritium models. *16th Symp on Fusion Technology (SOFT)*, London, UK, September 3-7, 1990.

Carmichael TJ: see **Chan HT** et al

Cenanovic M, Maureira HA, Malkiewicz TA, Lee JT, Pullia LS.
Applications of electromagnetic technology. *Stelco R&D*, Burlington, ON, March 23, 1990.

Chan AM: see **Dowlati R*** et al

Chan HT, Carmichael TJ, Lau KC, Vorauer A.
Design and construction of a coal fly ash storage mound. *CSCE Conf*, Hamilton, ON, May 16-18, 1990.

Chan HT, Crawford AM, Lau KC.
Compression behaviour of clay-based backfill under large hydraulic loading. *Materials Research Society Fall Meeting*, Boston, MA, November 28-30, 1990.

Chang SD, Hawthorne SH.
Measurement of flue gas flowrates for retrofitted FGD plant design. *EPRI/EPA SO_2 Control Symp*, New Orleans, LA, May 8-11, 1990.

Chang SD, Cheh CH, Leinonen PJ.
Demonstration of carbon-14 removal at CANDU nuclear generating stations. *21st Nuclear Air Cleaning Conf*, San Diego, CA, August 13-16, 1990.

Cheh CH: see **Chang SD** et al

Chisholm WA.
Ontario Hydro's lightning detection system. *IEEE Power Engineering Soc Winter Meeting, Lightning & Insulator Subcommittee*, Atlanta, GA, February 4-9, 1990.

Christie AE: see **McKinley RS** et al, **Patrick PH** et al

Chu FY.
R&D career opportunities & challenges in the energy sector. *Board of Trade of Metropolitan Toronto, Business Day Panel*, Toronto, ON, November 13, 1990.

Chu FY: see **Braun J** et al, **Vieira CS*** et al

Clark MA: see **Westwood HJ** et al

Crawford AM: see **Chan HT** et al

Cress SL.
"FUSCORD" probabilistic computation of fuse coordination bandwidth. *MEA Computer Applications Seminar*, Toronto, ON, November 8, 1990.

Cress SL.
Ontario Hydro's experience with transformer fuse operations. *CEA E&O Division Spring Meeting, Distribution Transformer Committee*, Montreal, PQ, March 29, 1990.

Cress SL, Motlis J.
Temperature rise of submarine cables on riser poles. *CEA E&O Division Fall Meeting, Distribution Power Cables Committee*, Victoria, BC, November 5, 1990.

Dawson CW: see **Barton RA** et al

Dayal R, Jakubick AT, Reardon EJ*.
Grout carbonation studies for evaluation of radiocarbon attenuation by cement-based backfill. *92nd Annual Meeting of the Am Ceramic Soc*, Dallas, TX, April 22-26, 1990.

Deans JJ: see **Sato JA**

Di Biasio E: see **Manolescu AV** et al

Doherty PE: see **Brennenstuhl AM, Brennenstuhl AM** et al

Donnelly KE: see **Morrison HD** et al

Dowlati R*, Chan AM, Kawaji M*.
Comparison of void fraction and friction pressure drop in adiabatic two-phase flow between a horizontal in-line and staggered tube bundle. *111th ASME Winter Annual Meeting*, Dallas, TX, November 25-30, 1990.

Dowlati R: see **Ogram GL** et al

Dunstall TG, Ogram GL.
Diffusion and biological oxidation as component processes regulating the deposition of tritiated hydrogen to soils. *IAEA Workshop on Tritium Safety and Environmental Effects*, Aiken, SC, October 15-19, 1990.

Dunstall TG: see **Brennenstuhl AM** et al

Edgar JN, Kuffel J, Mintz JD.
Assessment of the contamination performance of transmission class composite insulators using the clean fog test procedure. *CEA Spring Meeting*, Montreal, PQ, March 27, 1990.

Edgar JN: see **Kuffel J** et al

Elmoselhi MB, Warr BD.
Kinetics of hydrogen uptake by Zr-2.5 wt% Nb: effect of temperature and interfacial microstructure. *Intl Symp on Metal-Hydrogen Systems Fundamentals and Applications*, Banff, AB, September 2-7, 1990.

Elmoselhi MB: see **Ward CW*** et al, **Warr BD** et al

Endrenyi J.
Optimal preventive maintenance of repairable power system components. *IIASA Intl Meeting on the Safety and Reliability of Energy Systems*, Sopron, Hungary, July 1990.

Eygenraam MP: see **Manolescu AV** et al

Eyles WM: see **Pon CJ** et al

Filter R.
Update on separable connector interchangeability. *CEA Spring Meeting*, Montreal, PQ, March 26, 1990.

Fischer D.
Digital teleprotection: a new technology. *CEA Spring Meeting*, Montreal, PQ, March 26-29, 1990.

Flaman MT.
Need for new standard on the hole drilling method. *ASTM Meeting*, San Francisco, CA, April 24, 1990.

Fluke RJ, Weaver KR*, Ogram GL, Forrest CF*.
Aerosol behaviour in the water aerosol leakage experiments. *2nd Intl Conf on Containment Design and Operation, Canadian Nuclear Society (CNS)*, Toronto, ON, October 14-17, 1990.

Fluke RJ, Weaver KR*, Ogram GL, Forrest CF*.
The water aerosol leakage experiments: programme description and preliminary results. *2nd Intl Conf on Containment Design and Operation, Canadian Nuclear Society (CNS)*, Toronto, ON, October 14-17, 1990.

Fluke RJ: see **Ogram GL** et al

Freire-Canosa J: see **Sumar RN** et al

Goel AP: see **Pon CJ** et al

Greening FR.
Annulus gas deposit formation. *Nuclear Electric*, Berkeley Labs, UK, June 20, 1990.

Groeger JH*, Braun JM, Allen AL.
Application of ultrasonic NDE techniques for location and characterization of defects in epoxy composite insulators. *IEEE Intl Symp on Electrical Insulation*, Toronto, ON, June 4-6, 1990.

Gupta BK.
Research at Ontario Hydro in oil-paper insulation. *Electric Power Research Institute*, Palo Alto, CA, August 1, 1990.

Hanson WG: see **Anderson HL** et al

Hartlen RT.
Vibration signatures of nuclear reactor main coolant pumps: variations with transducer location and operating conditions. *3rd Intl Symp on Transport Phenomena and Dynamics of Rotating Machinery (ISROMAC-3)*, Honolulu, HI, April 3, 1990.

Hartlen RT, Barreca SL, Ko RG.
Sustained oscillations of pumped two-Ph flow in a closed loop. *3rd Intl Symp on Transport Phenomena and Dynamics of Rotating Machinery (ISROMAC-3)*, Honolulu, HI, April 4, 1990.

Hartlen RT, Weiss J*.
Main coolant pump testing at Ontario Hydro. *EPRI Main Coolant Pump Diagnostic Workshop*, New Orleans, LA, April 17, 1990.

Hathout I: see **Krishnasamy SG** et al

Havard DG.
Conductor vibration, wake induced oscillation and galloping. *Seminars on Understanding Transmission Line Design*, Toronto, ON, October 28-November 2, 1990.

Havard DG.
Control of conductor galloping. *Transmission Line Design Staff*, Calgary, AB, March 20, 1990.

Havard DG.
Line upgrading, uprating, and refurbishment - testing and refurbishment. *ESMO 5th Intl Conf on Transmission & Distribution Construction and Live Line Maintenance*, Toronto, ON, June 21, 1990.

Havard DG.
Why do overhead lines gallop and can we control them? *Department of Mechanical Engineering, McMaster University*, Hamilton, ON, November 7, 1990.

Havard DG, Macedo FX.
Refurbishment of overhead lines at Ontario Hydro. *Staff of National Grid Research and Development Centre*, Leatherhead, UK, August 20, 1990.

Havard DG, Pon CJ.
Galloping observations in Canada - 1988-1990. *CIGRE SC22, WG11, Task Force on Conductor Galloping*, Paris, France, August 29, 1990.

Havard DG, Pon CJ.
Use of detuning pendulums for control of galloping of single and two- and four-conductor bundle transmission lines. *CIGRE SC22, WG11, Task Force on Conductor Galloping*, Paris, France, August 29, 1990.

Havard DG: see **Krishnasamy SG** et al, **Pon CJ** et al

Hawthorne SH: see **Chang SD, Nguyen YV**

Herrmann O.
Applications of ICP-OES in Ontario Hydro. *Recent Advances in Plasma Spectroscopy Conf*, York University, Toronto, ON, May 16, 1990.

Herrmann O.
Keeping the lights on with spectroscopy. *Can Spectroscopy Soc Meeting*, Toronto/Hamilton Section, Toronto, ON, February 28, 1990.

Ho DC.
Operations Research applications in Ontario Hydro. *Can Operations Research Soc Annual Conf*, Ottawa, ON, May 22-24, 1990.

Hooton RD, Sato JA, Mukherjee PK.
Frost damage in non-air entrained hydraulic structures. *Am Concrete Institute Spring Convention*, Toronto, ON, March 18-23, 1990.

Jakubick AT: see **Dayal R** et al, **Koopmans R**

Jones EA.
Rationale for test criteria of live line maintenance protective equipment — phase 2. *Panel Discussion of ESMO-90 and IEEE*, Toronto, ON, June 19, 1990.

Kalyanam KM: see **Morrison HD** et al

Kherani NP, Shmayda WT.
Electron flux at the surface of titanium tritide films. *Intl Symp on Metal-Hydrogen Systems, Fundamentals and Applications*, Banff, AB, September 2-7, 1990.

Kherani NP, Shmayda WT.
Tritium - materials interactions: an overview. *Advanced Tritium Safe Handling Course, Ontario Hydro Research Division*, Toronto, ON, May 7-8, 1990.

King PJ: see **Brennenstuhl AM** et al

Ko RG: see **Hartlen RT** et al

Koopmans R, Jakubick AT.
Automated data acquisition for dam monitoring. *Can Dam Safety Assoc Conf*, Toronto, ON, September 17-19, 1990.

Kowalewski JJ: see **Patrick PH** et al

Krasznai JP, Vaughan SB*, Williamson AS.
Current issues in the management of low and intermediate level radioactive wastes from Ontario Hydro's CANDU reactors. *ANS Winter Meeting*, Washington, DC, November 11-15, 1990.

Krishnasamy SG, Senkiw GA, Havard DG, Pon CJ, Tabatabai M, Hathout I, Radhakrishna HS.
Testing of lattice towers for Ontario Hydro transmission line refurbishment program. *IEEE Power Engineering Soc Winter Meeting*, Atlanta, GA, February 4-7, 1990.

Krishnasamy SG, Tabatabai M.
Correlation of combined wind and ice occurrences. *5th Intl Workshop on Atmospheric Icing of Structures*, Tokyo, Japan, October 29-31, 1990.

Krishnasamy SG: see **Manolescu AV** et al

Kuffel J.
Digital recording for impulse testing of distribution transformers. *Transformer Manufacturers & Utility Inspectors, Ontario Hydro Research Division,* Toronto, ON, May 14, 1990.

Kuffel J, Edgar JN, Mintz JD.
Leakage distance requirements for transmission class composite insulators. *EPRI Workshop on Non-Ceramic Insulators,* Padre Island, TX, May 1-3, 1990.

Kuffel J, Li Y*, Janischewskyj W*.
Fitting routines for the evaluation of standard parameters of impulse waveforms acquired using an impulse digitizer. *CIGRE WG33.03 Meeting,* Cascais, Portugal, September 4, 1990.

Kuffel J: see **Edgar JN** et al

Lat MV.
A simplified method for surge protection of underground distribution systems with metal oxide surge arresters. *CEA Spring Meeting,* Montreal, PQ, March 26, 1990.

Lau KC: see **Chan HT** et al

Lawson WHS: see **Westwood HJ** et al

Lee HP.
Finite element analyses of sealed concrete container models. *6th World Congress on Finite Element Methods,* Banff, AB, October 1-5, 1990.

Lee HP.
Local effect on concrete containment due to pipe impact — coupled and decoupled analyses. *2nd Intl Conf on Containment Design and Operation,* Toronto, ON, October 14-17, 1990.

Lee JT: see **Cenanovic M** et al

Leinonen PJ: see **Chang SD** et al

Lichtenberger PC: see **Warr BD** et al

Lin X, Melo OT, Shepson P*, Hastie D*, Niki H*, Bottenheim J*.
Ozone production by natural hydrocarbon in central Ontario. *Am Geophysical Union Spring Meeting,* Baltimore, MD, May 27-June 1, 1990.

Lin X, Melo OT, Hastie DR*, Shepson DR*, Niki H*, Bottenheim JW*.
The use of photochemical model to interpret field oxidant measurements. *Can Institute for Research in Atmospheric Chemistry Regional Oxidant Research Workshop,* Downsview, ON, June 25-27, 1990.

Lin X: see **Melo OT** et al, **Ogram GL** et al

Loewen T, Perricone F.
Vibration signature analysis fundamentals for machine condition monitoring. *NRC Bi-Annual Meeting,* Toronto, ON, October 1-2, 1990.

Macedo FX: see **Havard DG**

Madge RC.
Diversity of digital teleprotection equipment. *IEEE Power Engineering Society Winter Meeting, Fibre Optics Subcommittee,* Atlanta, GA, February 7, 1990.

Malkiewicz TA: see **Cenanovic M** et al

Mancey DS.
The dissolution of magnetite. *Corrosion Colloquia, Institute for Materials Research,* MacMaster University, Hamilton, ON, November 29, 1990.

Mangal R.
SONOX process for controlling acid gas emissions. *New Brunswick Power Corporation,* Fredericton, NB, October 10, 1990.

Mangal R.
SONOX process for controlling acid gas emissions. *Nova Scotia Power Corporation,* Halifax, NS, October 11-12, 1990.

Mangal R.
SONOX process - slurry injection for SO_x /NO_x control. *Alberta Power,* Edmonton, AB, June 5, 1990.

Mangal R: see **Mozes MS** et al

Mannik L.
Laser welding of steels: relationship between laser power, penetration depth, welding speed, and beam polarization. *9th Intl Congress on Applications of Lasers and Electro-Optics,* Boston, MA, November 6-9, 1990.

Mannik L.
Ontario Hydro's industrial laser laboratory. *Laser Applications for Improved CANDU Reactors Conf,* Chalk River, ON, May 31, 1990.

Mannik L.
Overview of laser services at Ontario Hydro's industrial laser laboratory. *Can Industrial Laser Assoc Conf,* Edmonton, AB, April 18-20, 1990.

Manolescu AV, Mayer P, Krishnasamy SG, Di Biasio E, Eygenraam MP.
Development of high temperature superconductor/metallic conductor contacts for high current application in power system. *3rd Can Conf on High Temperature Superconductivity,* McGill University, Montreal, PQ, May 4-5, 1990.

Maureira HA: see **Cenanovic M** et al

Mayer P: see **Manolescu AV** et al

McIntyre NS*, Taylor KF*, Mount GR*, Weisener CG*, Davidson RD*, Brennenstuhl AM, Warr BD.
Three dimensional SIMS depth profiling of protium and deuterium in Zr-Nb alloy and its surface oxide. *38th ASMS Conf on Mass Spectrometry and Allied Topics,* Tucson, AZ, June 4, 1990.

McKay AM.
Morpholine decomposition in a model boiler at dissolved oxygen concentrations up to 500 ppb. *Use of Amines in Conditioning Steam/Water Cycles Conf,* Tampa, FL, September 25-27, 1990

McKinley RS, Christie AE, Sheehan RW.
Seasonal distribution and movement of radio tagged walleye and lake sturgeon in the vicinity of the proposed Mattagami River hydroelectric extensions. *CEA Hydraulic Power Section Program Spring Meeting*, Montreal, PQ, March 26-28, 1990.

Melo OT, Lin X, Ogram GL.
The contribution of NO_x to the ozone problem and the implications for NO_x controls. *CEA E&O Division Spring Meeting*, Montreal, PQ, March 26-29, 1990.

Melo OT, Moroz WJ*, Misra PK*.
Atmospheric diffusion experiments and models. *CIDA Seminar 1019 to the Electric Power Environmental Protection Research Institute*, Nanjing, China, March 14-20, 1990.

Melo OT: see **Lin X** et al, **Ogram GL** et al

Mills D.
Science and technology strategy in Canada. *Standing Committee on Industrial Science & Technology*, Ottawa, ON, March 8, 1990.

Mills D: see **Anyas-Weiss N** et al

Mintz JD.
Proposed elbow switching test method. *ANSI C119*, Minneapolis, MN, July 18, 1990.

Mintz JD.
The rationale for cable projects on in situ testing, and material evaluation. *CEA E&O Division Spring Meeting, Distribution Power Cables Committee, Task Force Group SD-117*, Montreal, PQ, March 27, 1990.

Mintz JD: see **Edgar JN** et al, **Kuffel J** et al

Morrison HD.
Photoreactor design for laser-based tritium separation. *RIKEN Symp on Laser Science*, Wako-shi, Saitama, Japan, January 17-18, 1990.

Morrison HD.
Pulse length dependence of trifluoromethane-t dissociation. *Laser Soc of Japan Annual Meeting*, Tokyo, Japan, January 25-26, 1990.

Morrison HD, Bartoszek FE, Donnelly KE, Kalyanam KM, O'Neill JA, Robins JR, Sood SK, Woodall KB.
Tritium separation at Ontario Hydro. *RIKEN Symp on Advanced Separation Technology*, Wako-shi, Saitama, Japan, February 7, 1990.

Morrison HD: see **Vieira CS*** et al

Mortimer WP.
The persistence and migration of wood pole preservatives. *Air & Waste Management Assoc Annual Meeting*, Toronto, ON, April 24, 1990.

Motlis J: see **Cress SL**

Mozes MS, Mangal R, Thampi RG.
Sorbent slurry injection for controlling SO_2 emissions. *40th Can Chemical Engineering Conf*, Dalhousie University, Halifax, NS, July 15-21, 1990.

Mukherjee PK.
A summary of changes in the 1990 edition of Canadian standards on concrete materials, methods of concrete construction, and methods of testing for concrete. *Am Concrete Institute, Eastern Ontario and Quebec Chapter*, Ottawa, ON, May 24, 1990.

Mukherjee PK: see **Hooton RD** et al

Ng MK.
CAD. *Ontario Hydro Research Division Staff*, Toronto, ON, February 23, 1990.

Nguyen YV, Hawthorne SH.
Ontario Hydro's R&D in post-combustion flue gas desulphurization. *40th Can Chemical Engineering Conf*, Dalhousie University, Halifax, NS, July 15-21, 1990.

Nickerson SB.
Autonomous robot for a known environment. *Electrical Research Department, Research Auditorium*, Toronto, ON, February 23, 1990.

Nickerson SB.
Autonomous robot for a known environment. *Los Alamos Center for Fusion Engineering, Los Alamos National Laboratory*, Los Alamos, NM, February 26, 1990.

Nickerson SB.
Autonomous robot for a known environment. *Premier's Council Technology Fund Assessment Committee*, Toronto, ON, September 26, 1990.

Northwood DO*, Meng X*, Warr BD.
Microstructure of Zr-2.5 wt% Nb alloy pressure tubing. *9th Intl Symp on Zirconium in the Nuclear Industry*, Kobe, Japan, November 5-8, 1990.

Oda SJ.
Industrial microwave heating applications. *25th Annual Intl Microwave Power Institute Meeting*, Denver, CO, August 25-29, 1990.

Ogram GL.
Future full scale model validation experiments: a discussion paper. *Workshop on Tritium Safety and Environmental Effects*, Aiken, SC, October 15-17, 1990.

Ogram GL, Dowlati R, Weaver KR*.
Studies of water aerosol behaviour using a small-scale flashing jet apparatus. *4th Symp on Nuclear Science and Engineering*, McMaster University, Hamilton, ON, October 1-2, 1990.

Ogram GL, Spencer FS, Lin X, Melo OT.
NO_x emissions from soils. *Can Institute for Research in Atmospheric Chemistry, Regional Oxidant Research Workshop*, Toronto, ON, June 25-27, 1990.

Ogram GL, Weaver KR*, Fluke RJ, Forrest CF*.
On the aerosol produced by a flashing water jet on a large-scale experiment. *Am Assoc for Aerosol Research (AAAR) Annual Meeting*, Philadelphia, PA, June 19, 1990.

Ogram GL: see **Bunnenberg C*** et al, **Dunstall TG, Fluke RJ** et al, **Melo OT** et al, **Russell SB**

O'Neill JA: see **Morrison HD** et al

Patrick PH.
Ontario Hydro research on zebra mussels. *Ministry of the Environment Workshop on Zebra Mussels*, Toronto, ON, October 16, 1990.

Patrick PH, Kowalewski JJ, Christie AE, Jennette BL*.
An acoustical technique to detect and possibly classify fish in confined reverberant environments. *Acoustical Soc of America Conf*, Pennsylvania, May 22-23, 1990.

Patrick PH: see **Anderson HL** et al

Perovic V.
Effects of microstructure and internal stresses on hydride precipitation in Zr-alloys. *University of Cambridge, Cavendish Laboratory*, UK, May 23, 1990.

Perovic V.
Hydride precipitation in zirconium alloys. *University of Cambridge, Department of Materials Science and Metallurgy*, Cambridge, UK, February 12, 1990.

Perricone F: see **Loewen T**

Pon CJ, Goel AP, Havard DG, Eyles WM.
Field testing of four conductor bundle spacer-dampers. *CEA E&O Division Spring Meeting*, Montreal, PQ, March 27, 1990.

Pon CJ: see **Havard DG, Krishnasamy SG** et al

Pullia LS: see **Cenanovic M** et al

Radhakrishna HS: see **Krishnasamy SG** et al

Ramani N: see **Anderson HL** et al

Rasile EM: see **Warr BD** et al

Ribbans DJ: see **Sumar RN** et al

Robins JR: see **Morrison HD** et al, **Vieira CS*** et al

Russell SB, Ogram GL.
ETMOD (Ontario Hydro's Environmental Tritium Model) update. *Workshop on Tritium Safety and Environmental Effects*, Aiken, SC, October 15-17, 1990.

Sato JA, Deans JJ.
Advanced materials and structures in civil applications. *Canadian Advanced Industrial Materials Forum (CAIMAF) Seminar*, Toronto, ON, February 27, 1990.

Sato JA, Deans JJ.
Low temperature polymer and cement-based concretes and grouts. *MTO Municipal Update Materials Course*, Toronto, ON, February 12-14, 1990.

Sato JA: see **Hooton RD** et al

Sauvé RG: see **Zougas A*** et al

Schumacher LC.
Investigation of mixed metal oxide oxygen electro-reduction catalysts. *Am Chemical Soc Symp on Electrochemical Surface Science*, Boston, MA, April 22-27, 1990.

Senkiw GA: see **Krishnasamy SG** et al

Sheehan RW: see **McKinley RS** et al

Sherar MD*, Bremner LA, Arron GP.
Preliminary experiments on the effect of combined DC and ELF AC magnetic fields on cell proliferation in monolayer and spheroid cell cultures. *USDOE/APPA/EEI Annual Review of Research on Biological Effects of 50/60 Hz Electrical and Magnetic Fields*, Denver, CO, November 4-8, 1990.

Shmayda WT: see **Kherani NP**

Simpson CJ: see **Anyas-Weiss N** et al

Sinclair AG: see **Zougas A*** et al

Sood SK: see **Morrison HD** et al

Spekkens P: see **Brown J** et al

Spencer FS: see **Ogram GL** et al

Stonkus DJ: see **Anandakumaran K**

Sulowski AC.
Fall protection in Canada and the USA. *Central Institute for Labour Protection, Seminar on Fall Protection, CIOP*, Lodz, Poland, June 7, 1990.

Sulowski AC.
Fall protection when climbing poles. *Electric Utilities Safety Assoc Conf*, Mississauga, ON, October 10, 1990.

Sumar RN, Armstrong PJ, Tulk JD, Ribbans DJ, Freire-Canosa J.
Container storage of CANDU fuel: Ontario Hydro's dry storage demonstration program. *CNS Conf*, Toronto, ON, June 3-6, 1990.

Tabatabai M.
Remote monitoring of transmission line wind and ice loads in Ontario Hydro. *CEA Winter Meeting*, Victoria, BC, November 5-9, 1990.

Tabatabai M: see **Krishnasamy SG, Krishnasamy SG** et al

Thampi RG: see **Mozes MS** et al

Tinkler MJ.
Development and field testing of a portable robotic system for hydraulic turbine runner repair. *Research Division Metallurgical Research Departmental Seminar*, Toronto, ON, January 26, 1990.

Tulk JD: see **Sumar RN** et al

Vascotto GL: see **Anyas-Weiss N** et al

Vasquez ER, Trass O*.
Liquefaction of coal with simultaneous grinding. *15th Intl Conf on Coal and Slurry Technologies*, Clearwater, FL, April 23-26, 1990.

Vieira CS*, Robins JR, Morrison HD, Chu FY.
The application of infrared technique in GIS diagnostics. *6th Intl Symp on Gaseous Dielectrics*, Knoxville, TN, September 23-27, 1990.

Vorauer A: see **Chan HT** et al

Wang L.
Recent development in power system reliability. *University of Washington*, Seattle, DC, March 8, 1990.

Ward CA*, Pataki L*, Warr BD.
Reaction of hydrogen with Zr02. *Intl Symp on Metal-Hydrogen Systems Fundamentals and Applications*, Banff, AB, September 2-7, 1990.

Ward CW*, Elmoselhi MB, Pataki L*, Warr BD.
Surface kinetics of hydrogen entry into zirconium films. *Conf on Surface Engineering: Current Trends and Future Prospects*, Toronto, ON, June 25-27, 1990.

Warr BD, Rasile E, Elmoselhi MB.
Microscopical and compositional analyses of oxides in Zr-2.5 wt% Nb following in- and out-reactor exposures. *Institute of Metals Conf on Microscopy of Oxidation*, London, UK, March 26, 1990.

Warr BD, Elmoselhi MB, Brennenstuhl AM, Newcomb SB*, McIntyre NS*, Lichtenberger PC.
Oxide characteristics and their relationship to hydrogen uptake in zirconium alloys. *9th Intl Symp on Zirconium in the Nuclear Industry*, Kobe, Japan, November 5-8, 1990.

Warr BD, Rasile EM, Brennenstuhl AM, Elmoselhi MB, McIntyre NS*, Newcomb SB*, Stobbs WM*.
The microscopical and compositional analyses of the oxides on Zr-2.5 wt% Nb in relation to their role as permeation barriers to deuterium uptake in reactor applications. *Institute of Metals Conf on Microscopy of Oxidation*, Cambridge, UK, March 26-28, 1990.

Warr BD: see **Elmoselhi MB, McIntyre NS*** et al, **Northwood DO*** et al, **Ward CA*** et al, **Ward CW*** et al

Westwood HJ, Lawson WHS, Clark MA, Lau TW*.
Identification and mitigation of creep damage in low alloy steel weldments. *Conf of Metallurgists*, Hamilton, ON, August 27-29, 1990.

Williamson AS: see **Krasznai JP** et al

Woodall KB: see **Morrison HD** et al

Zbroja S: see **Anderson HL** et al

Zielinski PA.
Stochastic water quality modeling - Monte Carlo versus analytical approach. *8th Intl Conf on Computational Methods in Water Resources*, Venice, Italy, June 11-15, 1990.

Zougas A*, Sauvé RG, Sinclair AG.
Efficient hourglass control for finite element analysis of 2-D solids. *CSME Mechanical Engineering Forum*, University of Toronto, Toronto, ON, June 5, 1990.

Significant Research Contribution

Ontario Hydro is developing a dry storage container (DSC) for the interim on-site storage and eventual transportation of used fuel from the Pickering NGS to future off-site disposal facilities. The Research Division is providing technical support to the Nuclear Engineering Department to ensure that the container can safely fulfill this purpose. Research and development (R&D) support has been considerable; enough to merit the program's choice as the 1990 Research Annual's Significant Research Contribution.

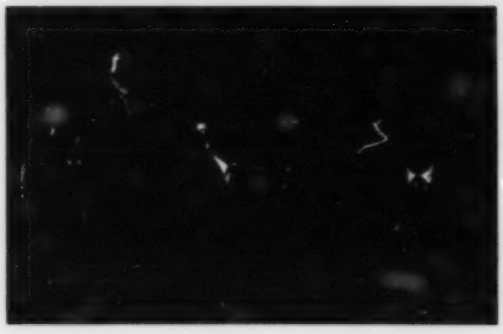
The DSC is essentially a double-walled steel container that utilizes reinforced high-density concrete, for strength and radiation shielding. A lid of similar construction is welded to the container. Civil Research Department developed and tested the concrete to optimize the density and high strength needed for radiation shielding and structural integrity. Coatings to protect the steel from corrosion and to facilitate decontamination procedures are being developed in the Chemical Research Department. Metallurgical Research Department performed extensive testing to assess various welding processes, inspection techniques, and remote welding technology. This work will assist in the selection of the most suitable weld joint design and in the preparation of technical specifications for the lid closure welding system and facility to be installed at Pickering NGS.

Mechanical Research Department took on the responsibility of performing the required AECB licensing tests. To meet the transportation requirements, the container must be able to survive severe impact followed by exposure to intense fire without escape of radioactive material or gases. To reduce costs, scale models were constructed, and these were extensively tested to gain an understanding of the container's performance.

AECB transportation regulations specify that the DSC be subjected to a minimum of two drops: one from a height of 9 m onto a flat, unyielding surface, and another from 1 m onto a solid steel bar projection. During the tests, accelerometers measured the impact acceleration of the container's body, and strain gauges the outer surface strain. The DSC was tested between drops for cracks and leakage. Additionally, analytical modelling was developed to emulate the container's structural integrity during impact. Drop test results from the quarter-scale model have been compared to analytical results to validate the structural response of the full-scale DSC.

Fire testing of the quarter-scale model was carried out by igniting the DSC with kerosene and engulfing it in flames for 30 minutes at 800°C. Temperature and pressure measurements as a function of time were taken both during and after the fire test for a period of 23 hours. Fire test results demonstrated that the integrity of the DSC model was maintained and that the DSC survived postulated accident conditions.

Half-scale drop tests similar to those performed on the quarter-scale model are scheduled during 1991. These tests will be crucial to attaining the AECB Design Approval Certificate.



The development of the DSC involved many experts from several disciplines within Ontario Hydro. Here at Babcock & Wilcox's fabrication plant in Cambridge, where the half-scale model was assembled, are some of the Research Division team members (from left to right) Jack Lee, Dimitrios Taralis, P K Mukherjee, and Peter Maak.